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Independent Verification Testing

Analyses of Alternatives for Conducting Independent Verification Testing of Environmentally Qualified Safety-Related Equipment

Prepared by L. L. Bonzon

Sandia Laboratories

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Prepared by
L. L. Bonzon

Sandia Laboratories
Albuquerque, NM 87185

Prepared for
Division of Reactor Construction Inspection
Office of Inspection and Enforcement
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555
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ABSTRACT

This study provides an analysis of alternatives for conducting independent verification testing of environmentally qualified safety-related equipment which is required to operate in nuclear plant safety systems. Three major alternatives were costed and compared: (1) NRC dedicated test facility; (2) NRC contracts for testing to existing test laboratories; (3) NRC review and witnessing of vendor tests.

To formalize the evaluation, eleven specific criteria were identified against which the alternatives were compared. None of the alternatives singly show clear advantage; but in the dual combinations, an "optimal" alternative emerges when alternatives 1 and 3 are considered in union.

This study also illustrates the magnitude and immediacy of the equipment environmental qualification issue. It recommends that dedicated NRC staff be assigned to qualification programs review and that other NRC staff comtinue this study to define, coordinate, and implement an optimal alternative.

EXECUTIVE SUMMARY

On April 13, 1978, the Commissioners issued a memorandum and order to the US Nuclear Regulatory Commission (NRC) staff that included 10 directives resulting from the Union of Concerned Scientists' petition dated November 4, 1977. Directive 5 sets the background for this report and analyses:

> "Provide the Commission with an analysis of alternatives (including estimates of resource requirements and potential benefits) for conducting independent verification testing of environmentally qualified equipment which is required to operate in safety systems ..."

The Office of Inspection and Enforcement (IE) responded to this directive by outlining a plan for the analysis of three major alternatives available to the Commission:

> "In essence, the plan consists of analyzing the following three alternatives each representing a course of action that will provide greater NRC involvement in equipment environmental qualification than presently exists.
>
> 1. NRC environmental test facility
>
> 2. NRC contracts environmental testing to existing DOE or independent laboratories
>
> 3. NRC review and witnessing of vendor tests conducted to meet NRC requirements."

Combinations of these alternatives were to be considered in search for the optimum method of monitoring and controlling the adequacy of safety-related (or, Class 1) equipment qualifications.

Complementary to the directive and to the implementing plan, the NRC conducted a stepped-up investigation relative to safety-related equipment qualification issues. Specifically, IE issued circulars and bulletins to cognizant nuclear industry as well as Special Temporary Instructions to the regional inspectors. As a direct outgrowth of these measures, and

along with increased licensee activity, more than 20 separate safety-related equipment items in over 20 separate plants were initially identified as having serious deficiencies in their qualification program packages. Such findings support the concept of and need for increased, and direct, NRC involvement in equipment environmental qualification and support the underlying premise for this study and report.

Preparatory to the detailing of the alternatives it was necessary to specify those areas common to the alternatives and the criteria to be used for intra- and interalternative evaluation. First, following the IE implementing plan outline, the analysis was directed toward:

1. Environmentally sensitive safety-related equipment, located in areas potentially exposed to a harsh environment, that is required to function during or following a design basis event for safe plant shutdown or otherwise required to mitigate the consequences of an accident.

2. Equipment currently being supplied and installed in plants under construction and such equipment approved for use in the future.

United Engineers and Constructors (UEC) participated in this "backlog" equipment definition and description. Some 28 generic equipment items were identified. For each generic equipment, 1 to 5 manufactureres were identified; for each manufacturer, 1 to 4 equipment "types" were identified. In total, the equipment "backlog" exceeds 140 separate equipment types.

Second, under Alternatives 1 and 2, this equipment "backlog" was to undergo an "acceptable" verification test scope. After review of the specific and applicable guidance (i.e., IEEE standards, Regulatory Guides, Branch Positions), a "universal test profile" was selected as outlined below.

Test	Test Conditions	Required Test Time*
1. Initial inspection and baseline functional test	As specified by specimen design	Variable
2. Accelerated thermal aging	Specimen placed in hot-air-circulating oven at temperature between 100° and 150°C	7 days
3. Intermediate functional test	See Item 1	
4. Exposure to gamma radiation (aging and accident dose)	200 Mrad at a rate of approximately 0.5 Mrad/h	20 days**
5. Intermediate functional test	See Item 1	
6. Vibrational aging	Specimen subjected to low level vibration at selected frequencies	2 days
7. Intermediate functional test	See Item 1	
8. Operational aging	Specimen cycled through 2000 to 100,000 cycles or accelerated continuous operation, as appropriate	Variable
9. Intermediate functional test	See Item 1	
10. Accident (HELB) simulation	In general accordance with profiles in IEEE 323-1974	30 days
11. Final functional test and inspection	Measure characteristic parameter to evaluate effect of testing on functional capability of specimen. See Item 1	

*Exclusive of test setup and setdown times.

**Assuming an average of 20 hours of radiation exposure per day.

Third, the evaluation of partially independent alternatives is largely subjective. To formalize the evaluation, 11 specific criteria were identified as, more or less, inclusive and independent and were used as intra- and interalternative evaluation "yardsticks." To facilitate a semiquantitative alternative selection, a 1- to 9-point value was merited to the alternative, for each criterion as appropriate; "1" is most negative, "5" is neutral, "9" is most positive. The 11 criteria were:

1. Level of NRC Involvement: To what extent does the alternative afford the direct participation of NRC in equipment qualification/verification tests.

2. Immediacy of the Alternative: How quickly can the alternative be implemented and the desired results be initiated and/or obtained.

3. Costs: Initial, Yearly, Long-Term: Each alternative demands varying amounts of capital and manpower costs, yearly-support and maintenance costs, and long-term commitments.

4. Direct Control of Prior-Tests Verifications: The capability to conduct retests on as-installed, on-line plant equipment is a specific flexibility feature.

5. Flexibility: Each alternative offers varying degrees of "flexibility" to adjust the testing, scheduling, etc, or to accommodate changing needs, requirements, test results, and other influencing factors.

6. Degree of Control Available: The ability to directly influence the timing, nature, direction, goals, etc of the verification tests is the ability to respond in a timely manner.

7. Long-Term Use Potential: Assuming that a long-term continuing need for independent verification testing or resultant studies is recognized, the alternatives offer varying degrees of long-term use potential.

8. Staffing Levels Required From NRC to Implement Alternatives: A specific recognized cost is the direct manpower allocation from within authorized NRC employment ceilings.

9. Historical/Chartered Function of the NRC: Direct involvement in equipment tests per se has not been an historical NRC function. Nor is the NRC (clearly) chartered to conduct qualification tests.

10. Dependence on the Supplier/Vendor: All alternatives have certain difficulties with adequate and timely test equipment supply; other concerns can be visualized, such as clustered scheduling of vendor-conducted testing, schedule shuffling, or the like.

11. Conflict-of-Interest/Conflict-of-Participants-Interest: To assure "independence" is to clearly demonstrate that NRC-involvement is "at-arms-length" with other test participants (suppliers, contractors, testers, etc). Commercial test laboratory participants could jeopardize their industry relationships by conducting NRC verification tests.

Alternative 1 offers maximum potential for direct NRC involvement in verification tests through direct ownership and/or control of a dedicated test facility. Using the equipment "backlog" and "universal test profile" scenarios as bases, the alternative was detailed by Franklin Research Center staff in two phases. The Phase I study developed the facility signature on the basis of the availability of a "minimal set" of LOCA-simulation equipment; under Phase II the facility was sized on the basis of a "desired test rate." The result of the Phase I study was a $8M+ facility with a $5M annual operating budget (at peak testing operation) and a staff of 125+; to complete the "backlog" tests would require 4 years of full-time testing. Under Phase II, the desired test rate was established so as to complete the backlog in 1-1/2 years; this specific option resulted in a $15M+ facility with an $8M annual operating budget and 240+ staff. But either phase of Alternative 1 has the strongly negative factor of implementation delay; ignoring the potential frustrations associated with line-item Congressional budget entries, facility planning, construction, equipping, and shakedown implies a delay duration of almost 5 years from NRC commitment to first test results. In summary, Alternative 1 is not neutral in its scoring to the criteria; it ranks highly positive with respect to direct NRC involvement, control of prior-tests verifications, flexibility, degree of control, and conflict of interest; conversely, it is highly negative with respect to immediacy of implementation, costs, and the historical function of the NRC.

Alternative 2 represents a middle position because it makes maximum use of existing test capabilities, while assuring direct NRC involvement and control through judicious contracting and subcontracting. (A preparatory step in the evaluation of this alternative was the cataloging of that test capability; see Appendix C.) Again the equipment "backlog" and "universal test profile" scenarios apply, and the alternative draws heavily and relatively from the Alternative 1 analysis. Alternative 2 would be implemented through a captive major contractor (who, in turn, subcontracts all testing) having a staff of 40 and a $2M+ annual payroll. As in Phase II of Alternative 1, the testing backlog is to be completed in 1-1/2 years, at an estimated total subcontracting testing cost of $8.6M+. Even with no major capital facilities to be built or bought, it is estimated that 3 years will be required to achieve first test results under this alternative. In summary, Alternative 2 is somewhat neutral in its scoring to the criteria; it ranks highly positive with respect to direct NRC involvement; it is highly negative with respect to immediacy of implementation, the historical function of the NRC, and conflict-of-participants-interests.

Alternative 3 is a direct outgrowth of the historical and chartered function of the NRC, the review and witnessing of vendor test programs. Depending upon its level of implementation, it can be an absolutely minimal response with respect to direct, increased NRC involvement in verification tests, ranging from one additional staff and up. The alternative is unique in that no contractor is involved, no capital or test facilities are required, and no implementation delays need occur once an NRC-management decision is made to proceed. Negatively, the alternative offers no clear milestone for completion (i.e., as in Alternatives 1 and 2 which have the equipment "backlog" to complete). As a result, Alternative 3 is a long-term continuing effort. With no direct control that NRC can exercise, the industry will (nominally) set the pace, kind, and quality of testing. In reviewing the anticipated test loads, the (approximately) 97 plants currently docketed through 1992 may represent the equivalent of some 25 complete qualification test programs; the implication is that under this alternative, the NRC staff may be required to review and witness 25 times more tests than under Alternatives 1 and 2. Based on a 100% coverage scenario, this requires a staff of 75 NRC employees and a $4M+ annual budget. In summary, Alternative 3 is not neutral in its scoring to the criteria; it ranks highly positive with respect to consistency with the historical and chartered NRC mission, conflict-of-interest, and immediacy of implementation; conversely and negatively, it demands large staffing from within the NRC and allows no direct control or flexibility.

There is no ambiguity as to the "potential benefit" of any of these alternatives; they will provide greater NRC involvement in safety-related equipment environmental qualification. But this study cannot decide the "level-of-confidence" desired by the NRC staff or the Commissioners; its purpose is to formulate and formalize the trade-offs to achieve a final goal and level, and to detail the related, relative costs. In a direct comparison of the alternatives scoring against the criteria, and in a direct comparison of the alternatives against themselves, there is no clear advantage for any alternative singly. But in the scoring of the possible dual combinations of alternatives, an "optimal" alternative emerges when Alternatives 1 and 3 are considered in union; that combination scores highly positive with respect to all criteria. That is not to imply that a combined full implementation of both alternatives is necessary; in fact, these, combined, offered a mutualistic relationship that conceptually produces optimality, while assuring direct NRC involvement, flexibility in operation and mode of operation, and long-term basis and benefit.

This study also illustrates the magnitude and immediacy of the equipment environmental qualification issue. The first plant (Comanche Peak), subject to IEEE 323-1974, has already begun the formal qualification review process. There seems to be no other choice than to establish a dedicated branch within the NRC to define, coordinate, and implement an "optimal" alternative. Owing to the immediacy of the problem, this branch should first formalize and initiate an Alternative-3-like feature of NRC review and witnessing of vendor tests. Its second objective should be to define the level of NRC involvement, the form of the long-term involvement, and the initiation of implementing programs. This study is one basis available to guide those decisions.

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CHAPTER 1. INTRODUCTION

1.1 Background

On April 13, 1978, the Commissioners issued a memorandum and order[1] to the US Nuclear Regulatory Commission (NRC) staff that included 10 directives resulting from the Union of Concerned Scientists' petition dated November 4, 1977. Directive 5 sets the background for this report and analyses:

> "Provide the Commission with an analysis of alternatives (including estimates of resource requirements and potential benefits) for conducting independent verification testing of environmentally qualified equipment which is required to operate in safety systems...."

The Office of Inspection & Enforcement (IE) responded to this directive (e.g., Reference 2) by outlining a plan for the analysis of three major alternatives available to the Commission:

> "In essence, the plan consists of analyzing the following three alternatives each representing a course of action that will provide greater NRC involvement in equipment environmental qualification than presently exists:
>
> 1. NRC environmental test facility
> 2. NRC contracts environmental testing to existing DOE or independent laboratories
> 3. NRC review and witnessing of vendor tests conducted to meet NRC requirements.
>
> Combinations of these alternatives will be considered in search for the optimum method of monitoring and controlling the adequacy of equipment qualifications."[3]

On June 2, 1978, IE staff requested[4] that Sandia Laboratories incorporate the analyses into an existing work scope. Sandia responded affirmatively to that request by letter,[5] on June 5. Subsequently numerous conversations between Sandia and IE staff served to further delineate and clarify the work scope and to shape the analyses toward the goals suggested by the Commissioners.

Complementary to the directive and to the implementing plan, the NRC conducted a stepped-up investigation relative to safety-related equipment qualification issues. Specifically, IE issued circulars and bulletins to cognizant nuclear industry as well as Special Temporary Instructions to the regional inspectors. As a direct outgrowth of these measures and along with increased licensee activity, more than 20 separate safety-related equipment items in over 20 separate plants were initially identified as having serious deficiencies in their qualification program packages. Such findings support the concept of and need for increased, and direct, NRC involvement in equipment environmental qualification and support the underlying premise for this study and report.

1.2 Objectives, Scope, and Tasks

In detailing the original objectives to satisfy the purpose of the plan, the following five were identified:[4]

- Define viable alternatives for conducting independent verification testing of environmentally qualified safety-related equipment
- Determine the resources required for each alternative
- Define any constraints or limitations associated with each alternative
- Determine the benefits of each alternative
- Define a basis for evaluating and selecting the alternative or combination of alternatives that should be implemented.

Similarly, NRC staff made several decisions relative to the scope of the analyses:

- Alternatives, in addition to the complete independent testing of all safety equipment, shall be considered in the analysis.

- The analysis shall address environmentally sensitive safety-related equipment that is located in areas potentially exposed to a harsh environment and that is required to function during or following a design basis event for safe plant shutdown or otherwise required to mitigate the consequences of an accident. By definition then, the analysis will consider safety significant electrical, instrumentation and control, and electro-mechanical equipment.

- The analysis shall address equipment currently being supplied and installed in plants under construction and such equipment approved for use in the future.

Three alternatives were selected as (more or less) inclusive. Each represents a potential course of action that would provide greater NRC involvement in equipment qualification programs than presently exists and consequently would provide a higher level of confidence in the adequacy of environmentally sensitive safety-related equipment. Combinations of these alternatives were to be considered in the analysis to arrive at an optimized alternative.

- Alternative 1 - An NRC owned and operated environmental test facility capable of accommodating the equipment of interest.

- Alternative 2 - NRC contracts for independent verification testing of equipment with existing laboratories.

- Alternative 3 - NRC review and/or witnessing of vendor tests conducted to meet NRC requirements.

To provide the reader with a complete overview of the progression of the project, the major tasks that were originally outlined to complete the analysis are presented below. Generally, they are listed in sequential order.

- Equipment - The environmentally sensitive equipment within the scope of the analysis will be identified by category, type/model, quantity and size. A plant study will be used as a basis for estimating the total quantity of safety significant prototypes involved.

- Tests - An acceptable test scope for each equipment category will be defined using current standards such as IEEE 323-1974[6] and considering the current state-of-the-art for such technical areas as accelerated aging practices.

- Sample Size - The equipment study will identify the population of prototype safety significant equipment. This number will be considered the current "backlog" from which several sample sizes will be selected for analyzing the three alternatives and desirable combinations. Upon completion of the backlog a routine test rate representing the equipment modification rate will be estimated to establish the continuing work load for equipment proposed for use in future plants.

- Alternative 1 (NRC test facility) - An estimate of the costs involved in the construction, equipping and operating of a test facility capable of conducting the environmental tests in accordance with standards such as IEEE 323-1974 will be made in two ways. The first will assume a sequential test operation and contain sufficient test facilities to support maximum utilization of one test (autoclave) chamber; in this case the test rate will be established by the facility and completion of the backlog will be dependent upon that test rate. The second will assume a parallel test operation site where the test facilities will be adequate to accommodate a (selected) desired test rate.

- Alternative 2 (NRC contracted tests) - This task will include a study of the existing testing capabilities and availability of facilities. Each facility will be characterized with respect to size and test rate limitations. The costs associated with contract preparation/monitoring and conducting tests at these facilities will be determined with respect to several test-sample sizes.

- Alternative 3 (NRC review and/or witnessing of vendor tests) - A study of the manpower and expense associated with this alternative will be estimated by using several sample sizes. A subset of this alternative will address the benefits of upgrading the industry's present approach to qualification testing through a third party effort as an alternative to direct NRC tests.

- Test Specimen Costs - An estimate of the test specimen costs will be made for Alternatives 1 and 2. These costs will include assembly costs where necessary as well as shipment costs.

- Evaluation - This task will include identification of constraints and limitations associated with each alternative. The relative benefits of each alternative will include costs, degree of verification independence and rate of achieving the desired confidence level. A basis for a decision relative to the appropriate course of action will be provided in the form of a value/impact assessment.

It needs to be specifically stated that for all alternatives "verification" is a key concept. Equipment qualification is not an objective in any alternative; the qualification function will always reside with the nuclear power industry.

1.3 Division of Effort

To accomplish this study with efficiency and in a timely manner, it was appropriate to draw from recent work, and existing contractors, on a complementary NRC-sponsored program, the Qualification Testing Evaluation (QTE) program.[7] Three major contributors, and specific correlated program aspects, were coordinated and supported by Sandia personnel who had overall responsibility for this study.

The identification of generic and specific Class 1 safety-related equipment and their piece-part costing was delegated to staff of United Engineers & Constructors (UEC), Inc. That subcontract dovetailed with an existing study[7] at UEC, which was to assemble and/or determine the following information for incontainment equipment for a typical PWR nuclear station:

1. Complete listing of typical Class 1 equipment
2. Realistic ambient and accident environments
3. Physical construction of equipment and materials lists
4. Performance specification, service-life history, and maintenance schedule
5. General equipment vulnerability and "weak-links" where known by prior experience
6. Electrical/mechanical/environmental interfaces.

To complete the bases for this alternative study, UEC expanded the basic generic PWR list to include BWR specific equipment that could be (potentially) subject to high-energy line breaks. A more complete manufacturers list and specimen costs were also added for purposes of this study.

Essentially the whole of Alternative 1, the scoping and costing of a dedicated test facility, was conducted by staff of the Franklin Research Center (FRC), a Division of the Franklin Institute Research Laboratories (FIRL). The selection of FRC was also based, in part, on their current and complementary efforts in the QTE program. In addition, FRC has a long history of equipment qualification testing experience for the nuclear industry,[8] dating back almost 10 years. Most recently, FRC completed a very similar study[9] specifically directed towards the qualification of Class 1E electrical cable; that latter study has broad application, specifically with respect to the Alternative 1 task.

The third major contribution to the complete study was IE-staff input on several aspects of the program. In the Sandia response[5] to the IE request for assistance,[4] IE was asked to provide direct IE-personnel involvement for 3 to 6 weeks during the course of the study to provide direct program coordination. IE staff also agreed to provide other direct assistance as follows:

- Information on equipment modification rate (new product evolution), BWR specific safety-related equipment, and an internally generated list of Class 1 equipment and suppliers.

- Information on Regulatory Guide and Branch positions relative to the definition of test scopes for each generic equipment type.

- Direct participation in subcontractor reviews and peer review of draft/final submittals.

- Review of the (Alternative 2) questionnaire and mailing list, and their supplementation.

- Base information for Alternative 3 (NRC review and/or witnessing of vendor tests) including (1) estimates of vendor tests currently underway, (2) estimates of future test rates, (3) estimates of necessary levels of IE involvement and management, and (4) details on the concept of the benefits of upgrading the industry's approach to qualification testing through a third party effort.

1.4 Presentation of Information

The report content is intended as a complete description of all aspects of the program. The full text of subcontractor contributions are included as appendices, with summary presentations in the appropriate report sections.

Chapter 2 discusses, and elaborates on, the study alternatives and the supportive background for the alternatives. The specific approaches to the analysis of each alternative are presented in Chapter 3 as well as the common scenarios and the basis for comparison of alternatives.

Chapters 4, 5, and 6 discuss each alternative in turn, with an advantage/disadvantage format and a cost/benefit evaluation.

Chapters 7 and 8 formalize the evaluation of alternatives and present the summary and final recommendations of the study.

CHAPTER 2. ALTERNATIVES

2.1 Selection

The numbe of possible alternatives that will provide increased NRC involvement in safety-related equipment qualification and/or verification is large. It is therefore imperative that the alternatives selected for specific analysis be encompassing and any that are intermediate be keyed with realistic constraints that can be identified a'priori. It should then be possible to interpolate between the alternatives to the extent desired to evaluate gradations of philosophies.

Thus, the three principal alternatives examined in this report were so chosen:

1. Dedicated Test Facility - Estimate the costs involved in the construction, equipping, and operating of a dedicated test facility capable of state-of-the-art qualification and/or verification testing.

2. Contract Testing - Characterize existing testing facilities, their capabilities and availability, and the costs to conduct qualification and/or verification testing.

3. Surveillance of Vendor Tests - Estimate the manpower and costs associated with increased NRC review and/or witnessing of vendor qualification tests.

While there is no significance in their order of presentation and especially no implied order of preference among the alternatives, Alternatives 1 and 3 are bounding in a realistic sense. Clearly a dedicated test facility (Alternative 1) represents the ultimate in flexibility, independence and control; just as clearly, it is an extreme in terms of capital outlay and length of time to acquire first verification test data. These advantages and disadvantages must be weighed and balanced against the other alternatives. Alternative 3 encompasses the minimal approach to increased NRC involvement; even here, Alternative 3 is not absolute and its gradations could range from one additional inspector to many inspectors, depending upon the testing coverage selected, 0% to 100%. But in concept, Alternative 3 is a minimum with respect to addressing the equipment qualification issues.

Alternative 2 recognizes that test facilities currently exist which could be brought to bear against the stated problem and its solution. Hence, it is an intermediate alternative firmly based on a realistic constraint or circumstance (i.e., existing capabilities).

It perhaps should be acknowledged here that the prospect of increased NRC involvement in verification testing through direct or indirect means is not original to this report. For example, Reference 10 recommends "... that routine direct NRC inspection and testing of hardware be increased, and that data pertinent to quality decisions made in construction and operation of a plant be evaluated by the NRC on a routine basis." The important new feature of this study is the in-depth evaluation of alternatives and the elucidation of decision criteria from which the cost/benefit of these alternatives, or their combination, extrapolation, or interpolation, can be derived and evaluated.

2.2 Alternative 1 - Dedicated Test Facility

The original and full statement pertaining to the Alternative 1 task[4] was specified as:

> "An estimate of the costs involved in the construction, equipping and operating of a test facility capable of conducting the environmental tests in accordance with standards such as IEEE 323-1974 will be made in two ways. The first will include a sequential test operation and contain sufficient equipment to support maximum utilization of one test chamber. In this case the test rate will be established by the facility and completion of the backlog will be dependent upon the test rate. The second way will be a parallel test operation site where the equipment will be adequate to accommodate a desired test rate."

There are a number of key points and implied subtasks within the statement that require elaboration.

A sequential test sequence is assumed for purposes of defining the dedicated facility. It is not to be implied or inferred that that choice is current NRC policy. A sequential test is however representative of industry practice and the state-of-the-art. For defining the facility, the choice between simultaneous or sequential tests will have minimal effect (on cost, scheduling, and the like). However as the facility was scoped, a conscious recognition of the possibility for simultaneous testing was encouraged; for example, a dry irradiation cell was selected, at least in part, based on its ease of use for conducting simultaneous tests. The overall effect of test choice should be minimal, no more than a few percent of the projected facility cost.

Two approaches to the facility signature evaluation were selected. In the first (Phase I), the facility was to "...contain sufficient equipment to support maximum utilization of one test chamber." But as the study progressed, it became clear that LOCA-simulation tests, using just one (autoclave) chamber, were controlling (in time) to such an extent as to make facility operation too inefficient. In fact, Phase I was reinterpretated to mean the development of a facility signature assuming a minimal equipment set. The Phase I study proceeded assuming two LOCA-simulation chambers and the associated set of supporting facilities.

A second facility signature evaluation based on a "...desired test rate...," was Phase II of the task. This latter phase was a perturbation to the Phase I approach, in which the equipment backlog was selected to be completely verified by test in a specified period of time. In the course of completing Phase I, it was determined that the backlog testing could be completed in about 4 years (from initial facility operation). Eighteen months was then selected for the Phase II study as a shorter, yet reasonable, completion time. Within the 4-year and 18-month evaluations, there is sufficient information to allow the reader to infer other facility configurations for other test-completion times.

Certain information necessary to complete the Alternative 1 study is only implied within the first task statement, but specifically covered in other tasks statements; see Section 1.2. The facility characteristics depend directly upon an accurate assessment of the equipment backlog to be subjected to environmental qualification verification testing. This task was addressed in a separate study performed by UEC (Section 3.1). But in terms of effect on the facility signature, uncertainty of the equipment backlog would primarily be manifested as an error in the estimated time to complete the backlog of tests because more (or less) equipment should have been identified. The test chambers and support equipment are expected to be completely adequate for the generic equipment identified.

The specific test profiles also influence the facility (see Section 3.2). That influence is also manifested in the time-to-complete-the-backlog estimate. Generally, reasonable specific environment magnitudes do not sensitively influence the facility or its equipment. While the test profiles are necessarily specific in equipment qualification programs, it was not feasible or practicable for purposes of this study. Instead a "universal" test profile was selected, based on current and historical practice and after evaluating the applicable standards and guidance. The readers must be cognizant of this factor since the effect is indirect as well as direct; for example, it would not be possible to do testing of two generic equipment items simultaneously if their test profiles were very different. Why then is a universal test profile sufficient? It is simply because the concept appplicable to this study, "verification," will allow enveloping whereas "qualification" is specific to a plant profile.

Certainly implied in a new facility is its useful life beyond any immediate requirements. While this is not specifically a part of the study, it is one consideration in detailing the facility. After the equipment backlog is complete, other uses for the facility should be realizable with minimal modifications and facility rework. Certainly "new" qualified products will provide a routine work level of verification tests; but another important function could be its utility as a research vehicle in examining and developing test methodologies. The latter function dictates a somewhat general, modifiable, and over-designed facility concept.

2.3 Alternative 2 - Contract Testing

The original and full statement pertaining to the Alternative 2 task[4] was specified as:

> "This task will include a study of the existing testing capabilities and availability of facilities. Each facility will be characterized with respect to size and test rate limitations. The costs associated with contract preparation, monitoring and conducting tests in these facilities will be determined with respect to several sample sizes."

Within this task statement, there are a number of subtasks and implied supportive bases to be addressed. Some are common to the alternatives so as to provide a uniform bases for analyses. For example, a sequential test series, the unit standard equipment backlog, and the universal test profile should be assumed. But in addition, there are major subtasks unique to this alternative.

To catalog the capabilities and availabilities of existing facilities, a questionnaire was prepared and sent to known and potential equipment qualifiers. The result was a large response and considerable raw data; this may have been a first attempt to catalog the majority of the environmental qualification testing capability. To prevent "shopping," the information is presented with a coded company list in Appendix C. The test capabilities are categorized by major affiliation. Such categorization is not required in the program outline, but should be of special benefit in future analyses if capabilities by government, academia, or private-industry breakdown are important.

Individual facility characterizations have been completed and are shown in the appendix. But individual analyses with respect to size and test-rate limitations seemed inappropriate. Rather the collective capabilities were analyzed for the scenarios common to the alternatives.

Implied in the task statement is the identification of a contracts management organizational structure to coordinate these contracts tests. The basic structure follows the suggestions found in the Alternative 1 study for a dedicated facility. But this organization has the feature of being expandable and expendable as the level of contracting effort varies with time.

2.4 Alternative 3 - Vendor Tests Surveillance

The original and full statement pertaining to the Alternative 3 task[4] was specified as:

> "A study of the manpower and expense associated with this alternative will be estimated using several sample sizes. A subject of this alternative will address the benefits of upgrading the industry's present approach to qualification testing through a third party effort as an alternative to direct NRC tests."

This alternative is uniquely different from the others. There are no common bases for comparison, such as equipment backlog, universal test profiles, or sequential test series; there is no direct control over testing within this alternative.

The benefits analysis of a third party effort is essentially another alternative, a redelegation of responsibility to a nongovernment agency. As such, it will be discussed in this report as a pseudo "fourth" alternative. It can be thought of as a supplement/complement to Alternative 3, which increases the confidence level of equipment qualifications, with no direct costs to the NRC or through subcontracting.

As mentioned above, the analyses of Alternatives 3 and "4" must rely on a relatively subjective comparison bases, since no common scenarios apply upon which quantitative comparisons can be made of all alternatives on an equal basis. Similarly, significant input to this task must be based on historical reviewer experiences, i.e., from IE staff directly.

CHAPTER 3. COMMONALITIES

It is appropriate in this chapter to discuss those areas and tasks which are essentially common to the alternatives, before the detailed discussion of the alternatives themselves in the next chapters. It is also necessary to discuss and clearly state the criteria for evaluation of the alternatives to provide a common understanding for the readership. In this chapter, four specific common areas are presented: safety-related equipment "backlog" enumeration, universal test profiles, common evaluation scenarios, and criteria for evaluation.

3.1 Equipment Backlog and Specimen Costs

In deciding the overall scope of the effort for this analyses, two basic decisions[4] affected the type, quantity, and vintage of the safety-related equipment to be included in the study:

- The analysis shall address environmentally sensitive safety-related equipment that is located in areas potentially exposed to a harsh environment and that is required to function during or following a design basis event for safe plant shutdown or otherwise required to mitigate the consequences of an accident. By definition then, the analysis will consider safety significant electrical, instrumentation and control, and electromechanical equipment.
- The analysis shall address equipment currently being supplied and installed in plants under construction and such equipment approved for use in the future. An estimate of the test specimen costs will be made for Alternatives 1 and 2; these costs will include assembly costs where necessary, as well as shipment costs.

For purposes of this study, Class 1 equipment per IEEE 323-1974[6] located in-containment or in areas potentially subject to high-energy line breaks (but outside containment) were identified. In general, the preponderance of this equipment is electrical, but as discussed below, certain mechanical, pneumatic, and electromechanical equipment have been identified (e.g., pneumatic actuators and enclosures). It should not be inferred that safety-related, ex-containment, equipment is unimportant. Rather the severe environment HELB-simulation testing is generally directed towards in-containment equipment and this equipment set defines the scope of the study.

The formalization of environmental qualification programs for non-electrical safety-related equipment is a rather new activity. The first industry standard[11] intended to blanket all safety-related equipment is currently in the draft stage; but its formal adoption is expected soon and should serve to be more "inclusive." Another equipment qualification approach, not so apparent in this country but under active investigation in some European countries,[12] is to do typetests of full-size equipment systems, e.g., a pump and motor in concert. It is evident then that evolving developments and/or requirements could influence the kinds and amounts of equipment to be tested; this could affect any proposed test facility, test schedule, or study conclusions. To first order, however, the effect (on costs, schedules, and the like) should be directly proportional to the final, total, test load.

The equipment listed was required to be that which is "...currently being supplied and installed in plants under construction and such equipment approved for use in the future." Equipment existing in operating nuclear stations is not the subject of this evaluation, except that it should happen to be the same as that currently being supplied and installed. The adequacy of qualification programs of on-line plants has been separately addressed in other recent USNRC studies.[13,14]

Within the context of this study, the "environments" of interest intentionally excluded seismic but only to focus the study emphasis to design-basis event hostile (e.g., LOCA, MSLB, HELB) environments. While seismic testing was excluded per se, normal vibrational loads were to be considered and accommodated in the alternatives and their evaluation; to some extent, the vibrational-loading test apparatus also relates to seismic testing.

To assure that the equipment specification was accurate and complete, United Engineers & Constructors (UEC), Inc, was asked to participate in the study on the basis of another, on-going complementary subcontract (see Section 1.3 and Reference 7). In developing the equipment list, UEC used a specific, circa-1983, PWR nuclear station as the reference plant. The equipment list specific to that plant was then supplemented with BWR-plant equipment (from a UEC-on-line-designed plant and from an in-progress EPRI study[15]), and through comment and review by Franklin Institute, USNRC, and Sandia staff.

The complete list, with some 28 generic equipment categories, is included as Appendix A. A portion of that list is shown in Table 3-1 to facilitate discussion.

UEC was asked to follow their standard bidders list process in identifying qualified suppliers of safety-related equipment. Generally this follows a "no more than five, not less than three" philosophy. It is possible that a qualified, or potentially qualified, supplier has been omitted. This is unintentional and merely reflects new entries into the market and/or UEC pre-evaluation of bidders. For purposes of this study, these few omissions cannot substantially alter the conclusions or the relative comparisons made.

For each manufacturer, a number of equipment "types" can be identified. UEC staff judged these types with respect to materials of construction, design, function, size, etc, in deciding on the suggested inclusive "type" set listed in Appendix A. Clearly this is a somewhat subjective exercise. In some cases, the subtleties between types may not be recognized <u>except</u> by typetests; that is, the list could lengthen by close examination for subtle type differences. To the best of their knowledge, UEC has concluded that the listed types represent 95% or more of the total equipment types that could be considered as "backlog" for qualification verification tests.

Table 3-1

Excerpt From Equipment List
(Appendix A)

EQUIPMENT	MANUFACTURER	MODEL NUMBER	PHYSICAL SIZE**	NUMBER OF TEST SPECIMEN REQUIRED	ESTIMATED COST UNIT	ESTIMATED COST TOTAL	REMARKS
1. Transmitters	Barton	763 764	5"h x 5"w x 8"d				
	Rosemount	1153DP 1153HP 1153AP 1153GP	9"h x 5"w x 5"d	11	$ 2,000	$ 22,000	
	Westinghouse	Veritrak 76	5"h x 5"w x 8"d				
	Foxboro	E11GM E11AM E11DM E13DM	14"h x 7"w x 7"d				
2. Actuators (Electric)	Limitorque	Series SB Series SBD Series SMB	14"h x 41"w x 21"d to 22"h x 41"w x 21"d	5	$ 3,000	$ 15,000	
	Rotork	NA1 NA2					
3. Actuators (Pneumatic) (Not 1E)	Matryx	26072-SR60	11"h x 60"w x 8"d				Due to the fact that these actuators are not electric (therefore not 1E), the estimated cost includes an allowance proportioned to the price based on UE&C past experience.
	Copes-Vulcan	D-100	6"diam x 17"h to 29"diam x 72"h	7	$1,500	$10,500	
	Hills-McCanna*	Ramcon R35B Ramcon R35BFS					
	Fisher	656 657 470					
	Masoneilan	37 71					

The physical size specification is important in estimating the facility required and, particularly, the time to complete the equipment backlog, for Alternative 1. Size, as well as other factors, controls the total number of tests required through the capability (or inability) of "doubling up" in each test. UEC staff used the standard product literature from these equipment suppliers to determine sizes.

Specimen costs were determined by UEC staff from responses to 69 letters sent to the various known suppliers. Excerpts from the letters are shown in Table 3-2. The costing of components is a part of the Alternatives 1 and 2 evaluation.

3.2 Universal Test Profile

It was originally intended that each generic equipment category be evaluated separately, and a specific test profile be generated for each, as suggested in the task description:[4]

> "An acceptable test scope for each equipment category will be defined using current standards such as IEEE 323-1974 and considering current state-of-the-art for such technical areas as accelerated aging practices."

Subsequently a review of the IEEE standards and the applicable Regulatory Guides as well as a brief review of some available industry-conducted qualification program documents was made by Sandia staff.

The specific guidance available is that a specific qualification program is to be generated for <u>each</u> equipment item <u>and</u> application. IEEE 323-1974 is the most applicable and specific guidance (in its Appendices); but its guidance is not absolute and cannot be, by definition or by charter. The Regulatory Guides, except in a very few cases, only endorse industry standards and do not offer unique or specific guidance.

Table 3-2

Excerpt From UEC Letter to Suppliers

Sandia Laboratories
J. O. Number 6602-002
Class 1E Equipment-
Price Request

Gentlemen:

United Engineers under contract with Sandia Laboratories, Albuquerque, New Mexico, is engaged in an investigative program funded by the U. S. Nuclear Regulatory Commission to evaluate the NRC's options in independently verifying the qualification tests of Class 1E components for nuclear power plants. In order to perform this task, United Engineers & Constructors Inc. is assisting Sandia Laboratories in compiling a list of safety related (Class 1E) equipment. This list will include an estimated cost of this equipment. To this end, we wish to enlist your cooperation and assistance in this effort.

The following equipment has been identified as generally used in a nuclear plant on safety related applications. Please submit a budgetary estimate price per unit for each of the items listed below:

Item No.	Model No.	Price
	Terminal Blocks	

If you believe, based on your experience, that other models of your equipment are also used in nuclear safety application that are not listed above, please feel free to submit additional budgetary price estimates. Price shall be F.O.B. manufacturer's facility.

It is not of immediate concern to this task if you have (1) environmentally qualified this equipment, (2) have an established quality assurance program, or (3) seismically qualified this equipment. However, if you have and the budgetary price you have quoted includes these, please indicate below:

(1) Equipment is nuclear qualified — Yes____ No____
Price Included — Yes____ No____

(2) Established quality assurance program meeting 10 CFR 50 Appendix B in the manufacture of this equipment. — Yes____ No____
Price Included — Yes____ No____

(3) Equipment seismically qualified — Yes____ No____
Price Included — Yes____ No____

Please respond by providing the information requested in the appropriate blank spaces set forth above and returning this letter.

In general, the industry guides endorse IEEE 323-1974 for typetest programs. In some cases, particularly in the older (than 1974) standards, a typetest program may be more specifically discussed; but these are an early version of the program finally formalized as IEEE 323-1974 (for example, see Reference 16). Even when specific numerical values are given, they are largely inapplicable; for example, IEEE 317-1976[17] specifies that "...accelerated thermal aging tests shall be in accordance with IEEE Std 98 and 101. The aging time at the minimum aging temperature shall not be less than 5000 hours." But this guidance is for thermal aging during materials test, not for typetests of the component. Some more recent standards devote some effort to an in-depth tutorial on aspects of typetesting; IEEE 381-1977,[18] in its Appendix B, devotes over four pages to a discussion of "Aging of Class 1E Modules;" P627[19] is almost exclusively tutorial by intent.

It is to be concluded then that the Standards and Guides are not specific. Conversely, since a qualification program is necessary for each equipment item and application, it is to be expected that the guidance could not be specific.

While the guidance is not specific, for purposes of this study, the general guidance is sufficient to allow generic qualification program(s) development. The elements of a complete program are presented. Coupling these with the historical industry-generated programs, adequate programs can be attained for purposes of this study.

Since the introduction of IEEE 323-1974, the qualification of new equipment has increasingly corresponded to its recommendations.[20] In an appendix in IEEE 323-1974 a generic DBE profile is presented and is reproduced as Figure 3-1. The conditions presented are representative and may need modification to assure their suitability to any specific equipment application. Industry is generally adopting at least the principal features of the profile: typical magnitudes, additional peak transient, typical stairstepped shape and step duration, rise- and fall-times, and saturated-steam conditions.

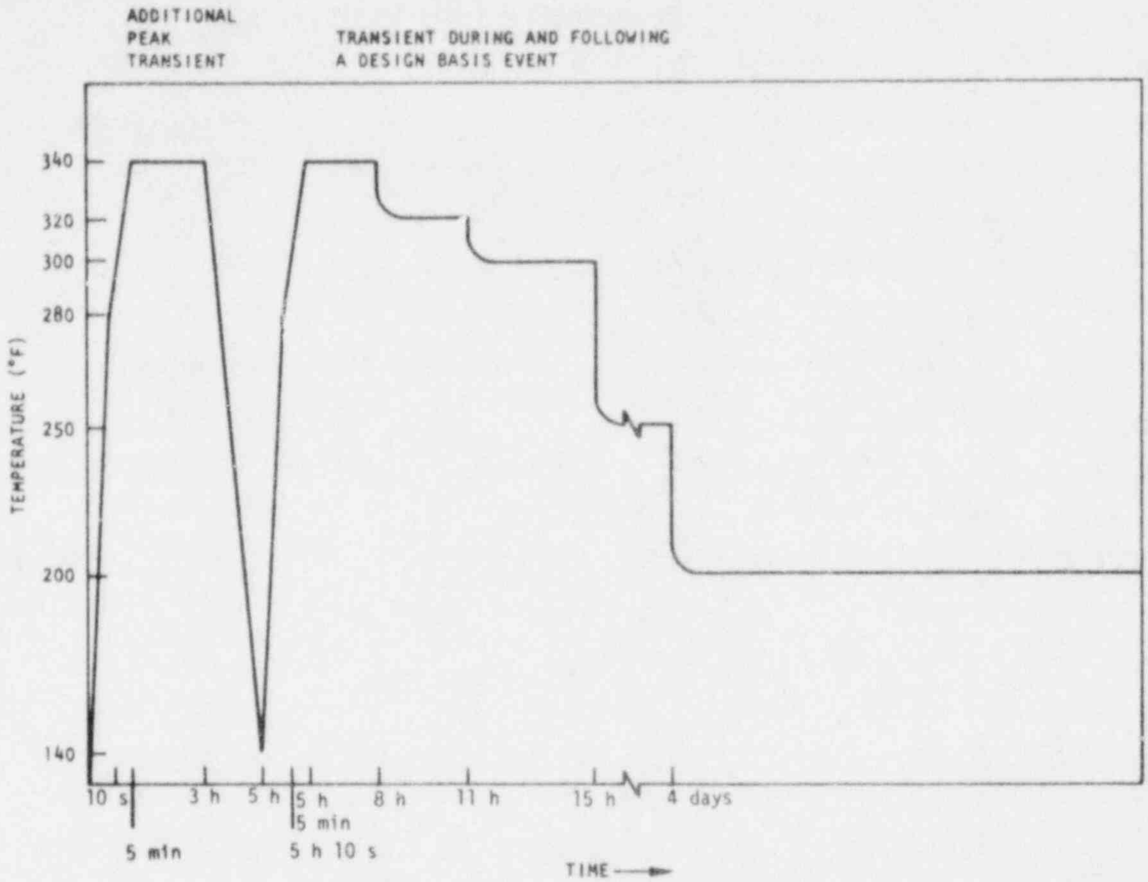


Figure 3-1 Test Chamber Temperature Profile for Environment Simulation (Combined PWR/BWR) (from Reference 6)

Following the review of the guidance and the general industry experience, FIRL staff was directed[21] as follows:

- The double-hump profile of IEEE 323-1974 will be assumed.
- No superheated steam tests, but indicate roughly the additional cost if it had been assumed.
- Assume 7-day aging tests (130° to 170°C range) in air-circulating ovens.
- Assume 200 megarads total dose at a maximum 0.5 megarad/hour dose rate.
- Assume 30-day LOCA tests.
- Testing is sequential: aging, radiation, then LOCA.

In addition, FIRL was asked to review their experience, once again, in an effort to arrive at generic test profiles. But regardless, the Alternative 1 FIRL report was to clearly state the assumptions and, where appropriate, to briefly discuss the costs/impacts if other assumptions would be used instead. Table 3-3, taken from the FIRL report in Appendix B, summarizes the selected qualification test program. This program is the universal basis for Alternatives 1 and 2 and their evaluations.

To anticipate some reservations of reviewers for the selected qualification program, we offer these few subjective arguments:

- The program is historically based and follows the general recommendations and guidance available.
- The study is not intended to critique, or extend the state-of-the-art of, qualification programs; hence, for example, sequential testing is specified.
- 200 megarads, with Cobalt-60, is a typical test value representing ambient-environment radiation plus the postulated accident dose.
- 0.5 megarad/hour is typical of industry experience, representing a realistic tradeoff between postulated environments and laboratory constraints.
- Saturated-steam tests are assumed; some superheat capability could be added with minimal overall cost increase to the complete facility or testing loads (if contracted, as in Alternative 2).
- A 30-day LOCA-test duration represents a subjective evaluation of what is required. It recognizes that testing needs to be actually conducted at less than, and more than, this single value depending upon specific equipment and specific application. The selection of 30 days should be a reasonable compromise value; the effect of some lesser, some greater, times should be effectively "averaged" in the selection of 30 days.
- 7-day accelerated thermal aging programs, in the 130° to 170°C range, are typical. In terms of effect on the Alternatives evaluation, the magnitude is largely insignificant. The duration could be important, but in the overall program, the 30-day LOCA test is still controlling in time.

Table 3-3

Elements of Typical Qualification Test Program

Test	Test Conditions	Required Test Time*
1. Initial inspection and baseline functional test	As specified by specimen design	variable
2. Accelerated thermal aging	Specimen placed in hot-air-circulating oven at temperature between 100° and 150°C	7 days
3. Intermediate functional test	See Item 1	
4. Exposure to gamma radiation (aging and accident dose)	200 Mrad at a rate of approximately 0.5 Mrad/h	20 days**
5. Intermediate functional test	See Item 1	
6. Vibrational aging	Specimen subjected to low level vibration at selected frequencies	2 days
7. Intermediate functional test	See Item 1	
8. Operational aging	Specimen cycled through 2000 to 100,000 cycles or accelerated continuous operation, as appropriate	variable
9. Intermediate functional test	See Item 1	
10. Accident (HELB) simulation	In general accordance with profiles in IEEE 323-1974	30 days
11. Final functional test and inspection	Measure characteristic parameter to evaluate effect of testing on functional capability of specimen. See Item 1	

*Exclusive of test setup and setdown times.

**Assuming an average of 20 hours of radiation exposure per day.

3.3 Common Scenarios

The costing, evaluation, and comparison of Alternatives 1 and 2 are done on the basis of common scenarios of equipment backlog and universal test profiles. It is possible to determine reasonably precise cost estimates. For uniformity, any Alternative 1 assumptions were subsequently adopted in evaluating Alternative 2, and Alternative 1 can be considered as a base case in that sense.

Alternative 3 shares none of the common scenarios discussed thus far; it, in fact, represents a unique approach from that in Alternatives 1 and 2. The only common bases for interalternative evaluation are then largely subjective as discussed in the next section.

3.4 Criteria for Alternative and Interalternative Evaluation

As must be expected, the evaluation of these pseudo-independent alternatives is somewhat subjective. It is then convenient to clearly delineate the criteria used in the evaluation prior to discussing the alternatives themselves; in this manner, the reader can formulate and formalize opinions as he proceeds through each alternative and can concentrate on the key features of each alternative.

In general, 11 separate criteria can be identified which should be, more or less, inclusive and independent; these are discussed below, but are not necessarily listed in order of preference or importance. To facilitate a "semi-quantitative" alternative selection process, the analyses of the alternatives will use a 1- to 9-point grading system with "1" being most negative, "5" being neutral, and "9" being most positive. As each alternative is discussed, a defense of the assigned "points" will be presented. "Most positive" or "most negative" is not an absolute designation; low cost is "most positive", whereas high flexibility is also "most positive."

3.4.1 Discussion of the Criteria

A definition/discussion of each criterion is presented below; Table 3-4 summarizes these criteria. (In the balance of the report, these criteria may be referenced by the number indicated in the table.)

Table 3-4

Alternatives Evaluation Criteria

1. Level of NRC Involvement
2. "Immediacy" of the Alternative
3. Costs; Initial, Yearly, Long-Term
4. Direct Control of Prior-Tests Verifications
5. Flexibility
6. Degree of Control Available
7. Long-Term Use Potential
8. Staffing Levels Required From NRC to Implement the Alternatives
9. Historical/Chartered Function of the NRC
10. Dependence on the Supplier/Vendor
11. Conflict-of-Interest/Conflict-of-Participants-Interests

Level of NRC Involvement: Here, the level of NRC involvement is to be construed to mean that direct participation in verification testing is to be desired to assure a high level of independence in the conduct of "...independent verification testing[3]..." The NRC is viewed as a completely independent arbiter, with the quality of any verification test results directly relatable to the level of their direct involvement. It is not unreasonable to interpret the Commissioners directive[1] as demanding a high degree of independent assurance.

Immediacy of the Alternative: A critical feature of any alternative is related to how quickly a solution can be brought to bear on the problem, just how quickly the alternative can be implemented and the desired results be initiated and/or obtained. With the recent controversy[22] over environmental qualification of safety-related equipment, and with increased public participation and pressures, the speed of alternative implementation may be the paramount feature. It is, at the very least, desirable to have a capability to respond to a recognized need in a "timely" manner.

Costs; Initial, Yearly, Long-Term: Direct costs associated with the alternatives is one quantitative basis universally applicable to all. Some alternatives also imply significant cost commitments over their succedent lifetime. In discussing the alternatives, consideration will be directed to capital and manpower costs associated with an initial investment, with yearly support/maintenance costs, and with any possible long-term commitments. At the same time, cost is not necessarily the absolute basis, rather the cost/benefit ratio of the alternative is a key feature.

Direct Control of Prior-Tests Verifications: An underlying assumption[3] for this study was that it would "...address equipment currently being supplied and installed in plants under construction and such equipment approved for use in the future." But a reasonable extrapolation might be to conduct, or have the capability to conduct, some verification tests on as-installed, on-line plant, safety-related equipment, especially for that equipment which is suspect on the basis of other testing or operating and historical experience. (See, for example, the concern over connector tests[8] and Commission-directed retests.[1])

This evaluation criterion is implicitly included under "flexibility," a separately-listed criterion, but it is so specific as to be separable and because it represents a particularly unique and desirable feature.

Flexibility: A rather intangible but attractive feature of any alternative can be loosely described as "flexibility." As noted, certain other criteria are included under this general term as well. While flexibility is not easily defined, and one must generally decide whether a new or different specific feature can be accommodated on a case-by-case basis, it is possible to estimate the relative flexibility of any alternative and among alternatives. A lesser known factor is the desired quantity of flexibility and the subliminal costs associated with increased flexibility. In the context that it will be used in this study, flexibility can be thought of as an intra-alternative feature rather than an interalternative one; that is, given a decision and selection of alternative(s), can the alternative(s) itself be considered to be "flexible" to accommodate new areas of interest?

Degree of Control Available: The ability to directly influence the timing, nature, direction, goals, etc of the verification tests is the ability to respond in a timely manner. Again, for a specific completely defined problem, control can be established a'priori; only the uncertainty of "absolute" and unchangeable problem definition impacts the need for, and degree of, control. Clearly, the ability to control or redirect the scope of work is a desirable feature.

Long-Term Use Potential: Assuming that a long-term continuing need for independent verification testing or related studies is recognized, the various alternatives offer varying degrees of long-term use potential. Clearly this rather subjective criterion can be neither a strongly negative nor a strongly positive factor when related to an equipment-backlog scope of work.

Staffing Levels Required from NRC to Implement the Alternative: Direct manpower allocations from within authorized NRC employment ceilings must be considered as a negative factor; the greater the manpower requirements within an alternative, the greater the impact on other NRC programs and commitments. This criterion is related to costing of the alternatives, but is distinctly separable by its nature and its potential impact.

Historical/Chartered Function of the NRC: Direct involvement in equipment tests per se has not been a function of, or within the routine experience of, the NRC.[10] Clearly, verification testing and/or research is within the mandate of the NRC. But care is necessary to avoid qualification or disqualification of equipment on the basis of qualification verification testing. A conflict may result from the opposing factors represented by the possibility of qualification/disqualification and the necessity to completely report all activities as required of NRC activities under "sunshine" laws.

Dependence on the Supplier/Vendor: Although somewhat dramatically stated, this criterion is possibly an extremum of the "Degree of Control Available" criterion. However, it has a significant distinction as well. This criterion suggests that potential difficulties exist with equipment suppliers at the front end of the test, rather than during the test cycle. These difficulties could be manifested as delays in supply, clustered scheduling of vendor-conducted testing, schedule shuffling so as to complicate inspection timing, or the like.

Conflict-of-Interest/Conflict-of-Participants-Interests: A particular feature of "independence" is to clearly demonstrate that NRC-involvement is "at-arms-length" with other test participants (suppliers, contractors, testers, etc). It will be necessary to assure that no conflict-of-interests occur, to avoid critical public review, and to assure the general acceptance of test data and results.

A related factor may be the concern of industry participants in such a program and results from the NRC-industry and industry-client relationships. With "industry" here defined as the equipment vendor and/or test organization, the industry may be uncomfortably faced with differing test results on same-type equipment. These differences may result from slightly differing tests (envelope vs specific-plant tests), slightly varying test methodologies, marginal equipment, and the like.

3.4.2 "Core" Criteria

The 11 criteria discussed in the previous section represent the chosen set of considerations for intra- and interalternative comparisons. But a narrower set would be actually applicable if the equipment-backlog tests are the only concern, there is no deviation from these tests, and there is no long-term need identified. The "core criteria" eliminate the advantages of flexibility, direct control, and the like. Table 3-5 lists these. These remaining seven criteria can be viewed as an (equally) weighted set; they could also serve for direct cost/benefit evaluations of the alternatives.

Table 3-5

Core Criteria

1. Level of NRC Involvement
2. "Immediacy" of the Alternative
3. Costs; Initial, Yearly, Long-Term
4. Staffing Levels Required from NRC to Implement the Alternatives
5. Historical/Chartered Function of the NRC
6. Dependence on the Supplier/Vendor
7. Conflict-of-Interest/Conflict-of-Participants-Interests

CHAPTER 4. ALTERNATIVE 1 - DEDICATED TEST FACILITY

A general description of Alternative 1 was given in Sections 2.1 and 2.2; those sections will be developed further in this chapter. It should be observed that this chapter is titled "dedicated" rather than "NRC" test facility (as it was previously described in Chapter 1). This may well be a minor point, with no need for elaboration, but it recognizes that the important feature of the facility is that it be NRC-controlled, independent, and dedicated to safety-related equipment qualification verification testing and/or qualification confirmatory research. The distinction is made to circumvent concern for the legal ramifications of outright NRC ownership of such facilities; nor is it critical to this evaluation that NRC have actual ownership of the facility.

4.1 Alternative 1 - Briefly

This alternative represents an extreme of the potential for direct NRC involvement in, and consequently maximum control over, safety-related equipment qualification verification testing. For this, and all, alternatives, "verification" is a key concept. Equipment qualification is not an objective in any alternative; the qualification function will always reside with the nuclear power industry.

Originally and specifically stated, the Alternative 1 task[4] was:

"An estimate of the costs involved in the construction, equipping and operating of a test facility capable of conducting the environmental tests in accordance with standards such as IEEE 323-1974 will be made in two ways. The first will include a sequential test operation and contain sufficient equipment to support maximum utilization of one test chamber. In this case the test rate will be established by the facility and completion of the backlog will be dependent upon the test rate (Phase I). The second way will be a parallel test operation site where the equipment will be adequate to accommodate a desired test rate (Phase II)."

The detailing of the facility was conducted by staff of the Franklin Research Center (FRC) and is presented in Appendix B. Their charter was to detail the Alternative 1 (Phase I and II) facility; they had no responsibility to evaluate the Alternative, internally or comparatively.

It is important to note that the detailing of the facility does not completely address all implied features of the alternative. Besides its evaluation against the criteria, it is necessary to compose and color its preamble (e.g., interim considerations until full operation) and its legacy (e.g., long-term facility use, benefit, and/or phase out). While the FRC report touches on these issues, Section 4.4 will address such considerations to complete the picture.

4.2 Review of the Ground Rules

To initiate the study by FRC, it was necessary to detail specific assumptions as bases. These have been thoroughly reviewed in Chapter 3 and will only briefly be reviewed here.

Equipment Backlog: United Engineers & Constructors (UEC) staff supplied the equipment list, by type, to be considered in this study, based primarily on a circa-1983 PWR plant design. The complete list, which includes some 28 generic equipment items, is included as Appendix A. The actual equipment list is tabulated into seven columns as described below:

- Equipment: Definition of generic Class 1E equipment located in an environmentally sensitive area. This area is defined as that where there is a potential for a hostile environment generated as a result of a high energy pipe rupture. Beside equipment located in-containment, equipment located in the pipe tunnels and the Primary Auxiliary Building equipment vault is addressed in this list due to the potential for a hostile environment, these are identified as being outside containment in the remarks column. In total, 28 Class 1E generic pieces of equipment used in typical Light Water Reactor plants are identified.

- Manufacturer: For each Class 1E generic piece of equipment, a list of manufacturers is shown. To keep the size of the project to a manageable size, only one to five vendors are listed for each generic piece of equipment. (Based on UEC's experience, UEC believes this list of manufacturers together supply approximately 90% to 95% of the market.)

- Model Numbers: Manufacturer model numbers recommended for testing are listed. This list does not contain every Class 1E model supplied by the manufacturers, but only those which differ in material and/or operation, so as to be a distinguishable "type." It was from this list of manufacturers and model numbers that inquiries were sent out to obtain an estimated price. Vendors were invited to submit prices for other models which are also used in nuclear safety applications. Based on vendor responses only a few model numbers were added or changed which tends to indicate the inclusiveness of the list.

- Physical Size: An envelope size rounded up to the nearest inch is listed for each generic piece of equipment. Since some manufacturer's equipment size or individual model size differ significantly, individual sizes are listed in these cases. A range of sizes is given for some equipment as appropriate (e.g., enclosures, terminal blocks, or cable).

- Number of Test Specimens Required: Quantity recommended for testing for each generic piece of equipment. This quantity is obtained by adding together the manufacturer model numbers for each generic piece of equipment.

- Estimated Cost - Unit: Average unit estimated cost for each generic piece of equipment. The cost was obtained using the following criteria:

    1. Average price from quotes submitted in response to UEC inquiries.

    2. The high price for each generic piece of equipment was omitted in this average because it was felt that the bid was not seriously reviewed by the manufacturer or full price of initial qualification was included.

    3. Due to the fact that each manufacturer was asked to note if the price included Class 1E qualification, seismic qualification and all quality assurance requirements, prices were generally taken from manufacturers that responded yes to all three questions. The exceptions are noted in 6 and 7 below.

    4. Price is based on 1978 dollars.

5. Allowance was added to each price of equipment to include special documentation, quality assurance procedures, welding procedures, and other special technical requirements that UEC requires on all Class 1E equipment. Additional price adjustments were made based on UEC past experience.

6. Pneumatic actuators and enclosures are nonelectrical (therefore, non-Class 1E) but nuclear safety related, and vendors do not address Class 1E qualification. UEC has included an allowance proportional to the quoted vendor price based on past experience for safety qualification testing.

7. Pressure switches and rotometers have not been qualified by any manufacturers and as noted in 6 above a proportional price has been added for Class 1E qualification procedures.

- Estimated Cost - Total: Unit estimated cost times number of test speciment required. Where equipment differs significantly, as in terminal lugs, 5KV cables and penetrations, separate quantities of test specimens required as well as a separate estimated cost is listed. For terminal blocks and enclosures where the number of poles and size vary significantly, a range of prices is listed.

Universal Test Profile: After a thorough review of the applicable Standards and Regulatory Guides, and after consultation with FRC and IE staffs, it was concluded that the generation of individual test programs for each generic equipment item was beyond the scope or needs of the study. A universal test profile was then adopted with these features:

- The double-hump profile of IEEE 323-1974
- No superheated steam testing, saturated-steam conditions only
- 7-day thermal aging in 130° to 170°C range in air circulating ovens
- 200 megarads total dose at a maximum 0.5 megarad/hour dose rate
- 30-day LOCA tests
- Testing is sequential: aging, radiation, then LOCA
- Vibration, but no seismic, as appropriate
- Operational cycling as appropriate.

Phase I: In Phase I, FRC staff were instructed to detail a complete facility based on the full-time use of one (LOCA) test chamber; sufficient ancillary equipment, services, facility, management, staff, etc, to support one chamber was then to be scoped. As that study progressed, it became clear that the single-chamber assumption was so controlling as to make (that) facility operation too inefficient. All study participants and sponsors then agreed that the logical interpretation of the Phase I statement implied a facility signature based on a "minimal set" of LOCA-simulation chambers. The Phase I study was completed assuming two chambers of different sizes.

To extend the discussion, it is worth briefly discussing the effect if just the single chamber had controlled the Alternative 1 study. Since test times of individual tests in sequence (see Table 3-3) dictate the total time to complete the equipment backlog, the single longest test, that can only be done in sequence, controls. The LOCA simulation test, at 30 days, is nearly twice as long as any other test; it is reasonable then to assume the total-backlog time to be proportional to the number of LOCA simulation chambers available. A one-chamber facility would require about twice the time to complete the backlog as a two-chamber facility. (Note that this must not be taken too far in extrapolation because of the capability to double up on testing the items.) While the backlog-time is doubled, that does not significantly reduce the facility or staffing required. The net effect is the time doubling and the significantly increased cost associated with four more years of facility operation devoted to the backlog.

Phase II: A corollary of the Phase I effort was to detail a facility on the basis of a "desired test rate" of equipment backlog. This was more appropriately stated as a specified period of time to complete the entire equipment backlog; the total time was selected as 18 months as a result of, and to contrast with, the Phase I study and its resultant 4-year estimate.

4.3 Alternative 1 - Summary of the Detailed Report (Appendix B)

On the basis outlined in Sections 4.1 and 4.2, FRC staff completed the full report on the Alternative 1, Phases I and II, dedicated test facility. Excerpts from that report (Appendix B) are presented in this section to precede the evaluation of the alternative against the criteria of Section 3.4; the executive summary, the Phase I, and the Phase II descriptions are separately presented in the following sub-sections.

4.3.1 Executive Summary (From Appendix B)

This study was conducted to estimate the resource requirements and costs involved in the designing, constructing, equipping, staffing, and operating of a laboratory facility dedicated to performing environmental qualification verification tests in accordance with IEEE Std 323-1974[6] and other applicable standards for reactor safety-system equipment used in nuclear power generating systems. It was conducted by Franklin Research Center (FRC) under contract to Sandia Laboratories.

The list of Class 1 safety-system equipment addressed in this study, which includes 135 specimens in 28 categories, was prepared by UEC. General guidelines for the laboratory and its capabilities were supplied to FRC by Sandia Laboratories and the NRC.

The proposed laboratory will be capable of performing the following tests: accelerated aging (thermal, vibrational and operational), gamma irradiation (normal and accident conditions), and simulation of a high-energy-line-break (HELB). Provisions were also made for possible future expansion of the scope of the laboratory to include research on aging of materials and the development and/or verification of qualification testing techniques. Therefore, the design of the facility and space allocation provide for potential future expansion of the staff and acquisition of additional laboratory equipment.

The design, cost, staffing and operating schedule of the laboratory were determined for each of two different operating modes, identified as Phase I and Phase II. In Phase I it was intended that the test specimens be processed essentially one at a time, in a sequential mode. This mode of operation economizes on the testing facilities, but extends the time required to complete all of the tests. Accordingly, a parallel mode of operation was considered in Phase II, with the testing facilities expanded to accommodate several test specimens simultaneously, so that the entire backlog of specimens could be processed in significantly less time than that required in the sequential mode of Phase I.

Because of the wide variation in the size of the test specimens, it was decided that two HELB test vessels, a small one in addition to one large enough to accommodate the largest specimen, should be provided in Phase I. Sufficient ancillary equipment was included to keep the larger chamber (in which most of the specimens will be tested) operating without holdup. With the laboratory so equipped, it was found that 4 years would be required to process the entire backlog of 135 test specimens.

The criterion chosen for Phase II of the study was that the laboratory be equipped and staffed so that all of the test specimens could be processed in 1-1/2 years, i.e., less than half the processing time required in the mode of operation of Phase I.

The time required to plan, design and build the laboratory; to equip it with laboratory, office, and support facilities; and to staff the organization and put it into operation was estimated as 4.5 years for either mode of operation.

A staff of 128 professional and administrative personnel is suggested to sustain operations in the sequential mode and 245 in the parallel mode. The estimate of overall costs and schedule for the two modes of operation are given below.

	Phase I Sequential Mode		Phase II Parallel Mode	
	Time (Years)	Cost (K$)	Time (Years)	Cost (K$)
Startup				
Construction of laboratory and initial checkout of facilities	4.5	10,900	4.5	19,752
Testing				
Backlog of 135 specimens	4.0	22,200	1.5	12,962
Follow-on				
Research initiated, testing effort reduced	1.5	10,400	2.0	20,325
Total	10.0	43,500	8.0	53.039

All equipment costs were based on 1978 prices; labor costs were based on 1978 rates for the first year, with an annual escalation rate of 10 percent. The cost of land and the installation of electric power, water supply and services were not included.

It was decided at the outset that the purpose of this study could be achieved by basing cost estimates largely on prior experience, and the time and funding limitations imposed on the study were consistent with this premise. Some supporting data for cost estimates were obtained through communication with potential suppliers of equipment and services; but this was the exception rather than the rule. Therefore, the accuracy of data supplied herein my be within ±50% of actual costs, which was considered adequate for the purpose of evaluating the concept of an independent verification laboratory against alternative concepts.

Before the design and construction of the laboratory can be initiated, in-depth cost analyses must be conducted to identify resource requirements and cost more accurately than was possible in this study. It is cautioned that peripheral studies such as building safety analyses, environmental impact studies and Occupational Safety and Health Administration requirements were not included in this study.

4.3.2 Phase I

4.3.2.1 General Test Program

The requirements for qualification of safety-system equipment by testing include:

- Accelerated aging of the specimen to simulate the maximum functional degradation that can take place prior to the occurrence of an accident that requires the equipment to perform a safety-related function
- Exposure of the aged specimen to simulated accident conditions to verify its functional capability during and following the accident.

Qualification testing programs, particularly accelerated aging procedures, must be tailored to the specific equipment being qualified; program elements may vary significantly among different categories of equipment. However, detailed analysis of different qualification programs was considered to be outside the scope of this study, which is based on a typical qualification program.

The elements of the typical sequential qualification program assumed in this study are listed below; a complete description was given in Table 3-3.

1. Initial inspection and baseline functional test
2. Accelerated thermal aging
3. Intermediate functional test
4. Exposure to gamma radiation (aging and accident dose)
5. Intermediate functional test
6. Vibrational aging
7. Intermediate functional test
8. Operational aging
9. Intermediate functional test
10. Accident (HELB) simulation
11. Final functional test and inspection.

4.3.2.2 Test Facilities, Laboratories, and Services

The test facilities required to perform the tests are summarized in Table 4-1. Column 1 of this table shows equipment function and column 2 equipment necessary to conduct the test. Column 3 lists the floor space required for equipment installation, including work space, while column 4 lists approximate equipment cost.

Physical sciences laboratories for detailed testing and analysis of specimens and for instrument calibration will be included to support the qualification test laboratory and gamma irradiation facility. These laboratories will be housed in a single, large room divided into separate areas for each of the physical sciences. The salient functions of each laboratory are described in the following list:

- Metrology Laboratory: The metrology laboratory will be used for the calibration and testing of monitoring instruments.
- Microscopy Laboratory: This laboratory will be used for microscopic analysis of failed components and materials following an HELB exposure to determine their failure modes.
- Chemical Analysis Laboratory: The chemical analysis laboratory will provide general chemical analysis support to the test laboratory. Functions to be performed include preparation of the chemical solution and the distilled water used in the HELB vessel and determination of the pH of the distillate to be recirculated in the HELB vessel.
- Electronics Laboratory: The functions of the electronics laboratory will include the fabrication of energizing circuits, functional check circuits and the calibration and maintenance of electrical and electronic instruments.
- Materials Laboratory: Testing of tensile strength, elongation and hardness of materials will be conducted in the materials laboratory.
- Radiation Calibration Laboratory: Instruments used for dosimetry in the radiation facility will be calibrated periodically in this laboratory. The calibration equipment will also be checked at regular intervals by procedures traceable to standards of the National Bureau of Standards.

Table 4-1

Test Facilities

Function	Facility	Estimated Floor Space Required (ft^2)	Estimated Cost (Dollars)
1. Thermal aging	3-ft x 3-ft x 4-ft-high oven	100	4,200
	6-ft x 6-ft x 10-ft-high oven	200	20,000
2. Vibrational aging	8-in-diam vibration table	50	500
	6-ft x 10-ft vibration table	100	10,000
	Two exciter controls		24,500
3. Gamma irradiation	Two hot cells	3,600	850,000
	Six cobalt-60 sources		1,500,000
	One 30-ton crane with 20-ft span	N/A	50,500 (installed)
4. HELB exposure	3-ft-diam x 4-ft-high pressure vessel	100	18,000
	6-ft-diam x 10-ft-high pressure vessel	200	36,000
	200-bhp steam generator	250	47,500
	200-kW steam superheater	100	90,000
5. Structural tests (force tests)	Steel I-beams ("strong-back")	200	10,000
6. Electrical tests (functional tests, operational aging and cable electrical property tests)	High-voltage power supply	100	N/A
	Low-voltage power supply		N/A
	Water immersion tank	500	5,000
	Dielectric strength test set	100	15,000
	Schering bridge	100	15,000
7. Test control and data acquisition center	See Table 4-2 of Appendix B	1,000	68,000
	Computer (comparable to a CDC Cyber 171)	500	1,000,000
8. Special handling equipment	One 10-ton crane with 20-ft span	N/A	29,000 (installed)
	One 30-ton crane with 45-ft span	N/A	59,500 (installed)
		TOTAL	$3,852,700

The specific types of equipment that will be provided in the support laboratories are illustrated by lists in Appendix B. Based on the cost of the instruments listed and allowing approximately 50% more for instruments not listed, the amount budgeted for equipping the support laboratories was $300,000.

The machine shop will contain the tools needed for the fabrication of test fixtures and for the modification and repair of test equipment. Table 5-2 of Appendix B lists the machine shop tools, with their cost totaling $134,100.

The service facilities, which will provide the necessary support functions for the efficient operation of the laboratory, are described below. Table 6-1 of Appendix B lists the equipment to be procured for these services. (The approximate costs are shown in parenthesis after each discussion.)

- Mailroom: Functions of the mail service will include the distribution of internal and incoming mail and the wrapping and posting of outgoing letters and packages. The costs of a mailing machine and additional mailroom equipment are listed; these costs were obtained from an office equipment supplier's catalogue. ($4,000)

- Receiving Department: The receiving department, which will be located adjacent to the storage room, will be responsible for the receipt, storage and shipping of test specimens, spare parts and raw materials. Access to the receiving department and storage room will be controlled for the purposes of security and quality control. ($4,000)

- Photography Shop: The photography shop, including a darkroom, will provide photographic and reprint services for the laboratory. During qualification testing, a photographer will be available to photograph test equipment arrangements and test specimens for use in test reports. ($12,500)

- Publications: Drafting, layout, blueprints, reproduction and printing, and all other services related to the publication of test reports will be provided to the laboratory by the publications department. ($46,450)

- Building Services: General building services such as painting, carpentry and grounds maintenance will be provided by the building services department. ($19,700)

- Dispensary: A dispensary will be located in the building to provide immediate emergency treatment of illnesses and conditions arising from industrial accidents. First aid stations will be located at various places throughout the building. ($2,800)

- Cafeteria: A cafeteria will be provided to supply a hot luncheon meal to employees during the five-day work week. Limited food and vending machine service will be available at all other times when the laboratory is open. ($22,800)

Total cost of all service facilities is estimated at $112,250.

4.3.2.3 Buildings and Layouts

It was considered advisable that the laboratory facility be located in a semirural area due to the sociopsychological consequences of constructing a laboratory equipped with a nuclear radiation test facility in the vicinity of a highly populated area. Because of its possibly remote location, the building should be self-contained and capable of supplying all operational needs as practical. In preparing a budget, land costs were not included in the overall estimate. Water, sewer, electricity, and fire protection were assumed to be readily available; the cost of connections for these utilities was not included in budget summaries.

A single building, comprising administrative and engineering offices, a high-bay test laboratory, and a secure gamma irradiation facility adjoining the test area, has been designed for the site. An overall view of the planned facility is illustrated in Figure 4-1.

With the exception of the adjoining irradiation facility, the building will be constructed of concrete blocks; low-maintenance materials will be used for window frames and doors. The irradiation hot cells will be constructed of high-density concrete.

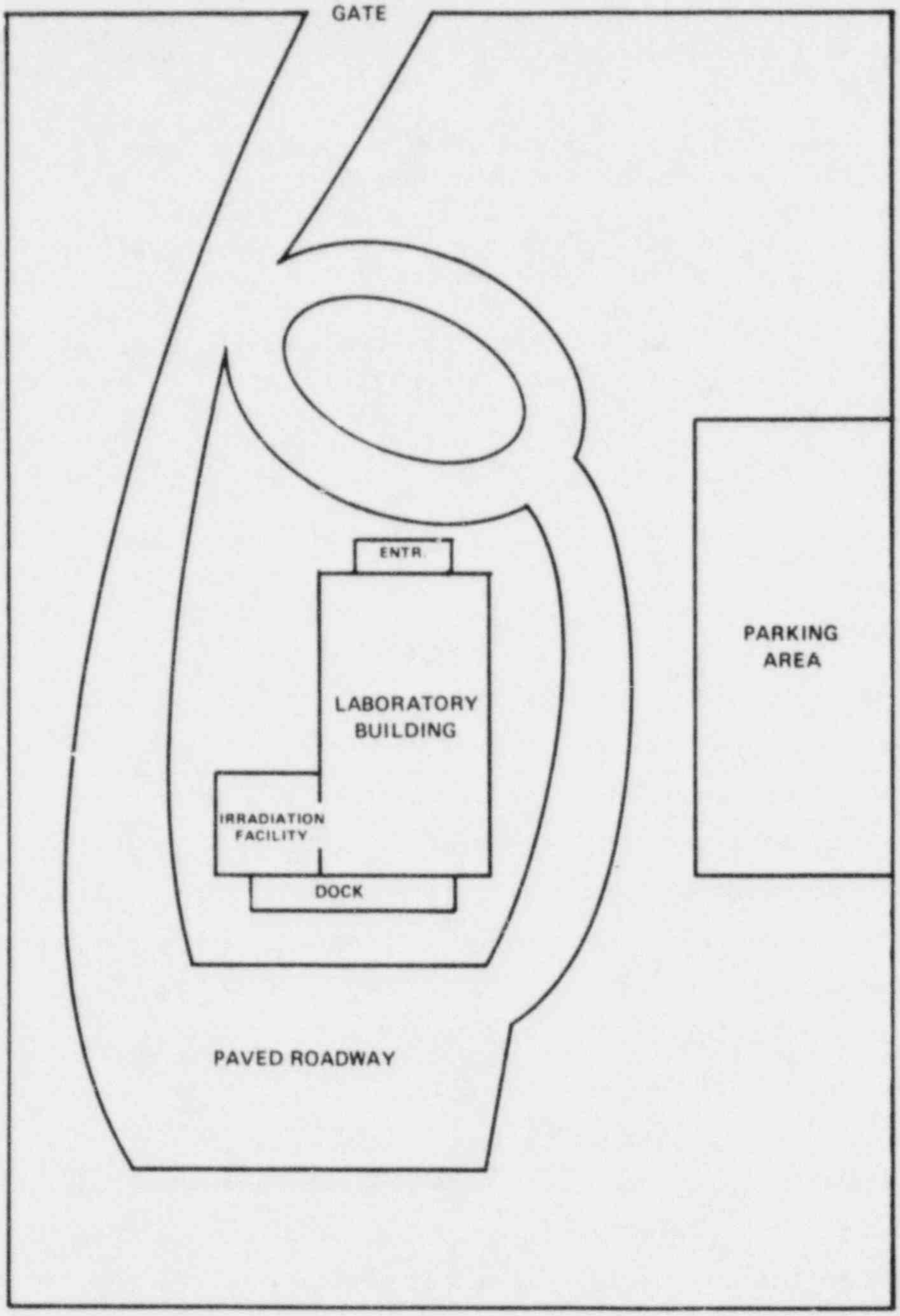


Figure 4-1 Plan View of Laboratory Site (Phase I)

The entire structure will cover approximately 56,500 ft^2 of floor space, including a 26,000-ft^2 area (170 ft long by 150 ft wide) set aside for office space. A second 26,000-ft^2 area will comprise the main laboratory and test areas, which will have a high bay (20-foot ceiling). The irradiation facility will require an additional 3,600 ft^2 of floor space.

A 12-foot-wide loading dock will span the width of the building at the rear and will be accessible by a railroad line and a paved truck thoroughfare. Test equipment, test specimens and raw materials will be delivered to the loading dock and then brought into the laboratory. The interior layout of the building is illustrated in Figure 4-2.

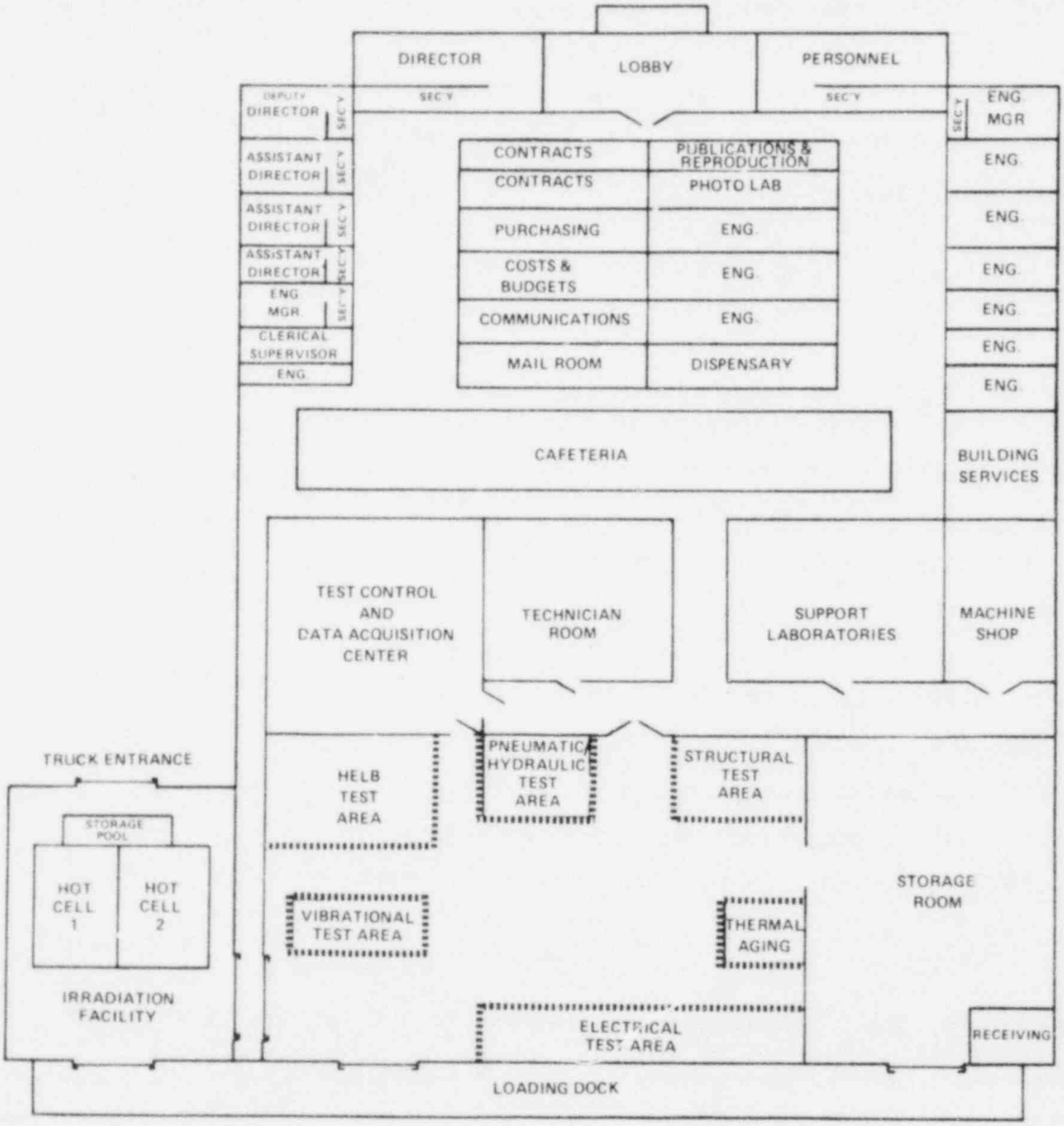


Figure 4-2 Plan View of Laboratory Building (Phase I)

The cost of erecting a laboratory building constructed of concrete blocks with brick facing was estimated as $\$60/ft^2$. This is a comprehensive estimate, including site excavation, the building foundation, the structure and roof, finished interior walls and carpets, heating, ventilation, and air conditioning. All specialized interior equipment, such as exhaust fans in the laboratories or restaurant facilities in the cafeteria, as well as minimal landscaping of the grounds and fencing and paving, are included in the cost estimate. Using the $\$60/ft^2$ estimate, the total construction cost of the proposed 56,500-ft^2 laboratory building, including the test laboratory, offices and gamma irradiation facility (minus the hot cells), was therefore estimated as $3,390,000.

4.3.2.4 Staffing and Organization and Staff Costs

The proposed staff organization is shown in Figure 4-3. A Deputy Director, who will report to the Laboratory Director, will be in charge of operations. Three Assistant Directors will head the areas of qualification testing, administration and building, and equipment. The Qualification Testing Manager and his staff of engineers and technicians will be responsible for conducting aging and accident simulation tests. Providing support services to the qualification testing staff, but reporting directly to the Assistant Director of Qualification Testing, will be the Qualification Supervisor and the Computer Services Supervisor.

The managers and supervisors responsible for administrative functions, such as accounting, personnel, purchasing, storage, mailing, typing, publishing, and printing services, will report to the Assistant Director of Administration.

The managers and supervisors responsible for services related to the maintenance and upkeep of the building and grounds, security, food services, and transportation will report to the Assistant Director of Building and Equipment.

A Quality Assurance Manager will report directly to the Deputy Director.

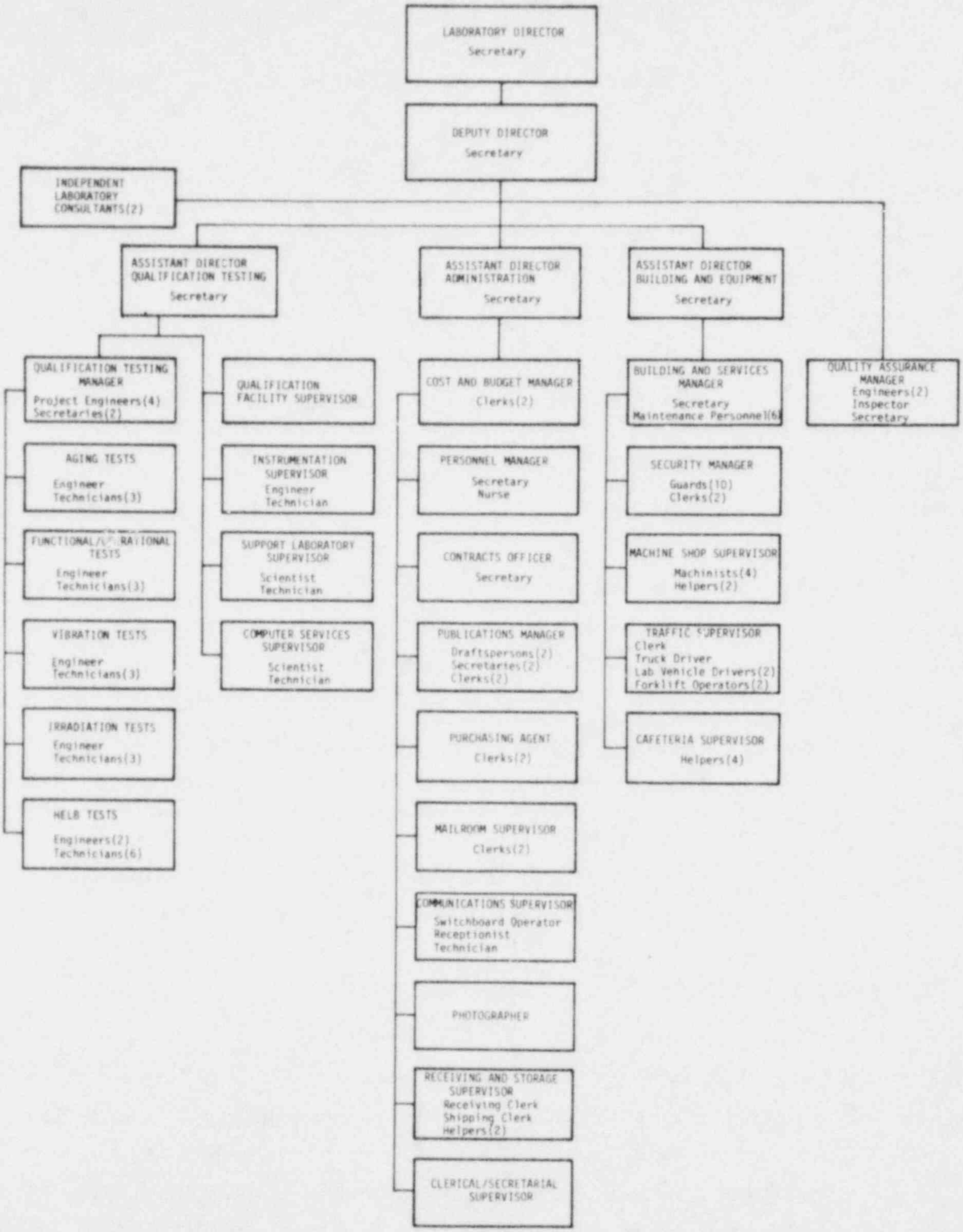


Figure 4-3. Recommended Staffing Level and Organization Chart for Phase I

Two full-time consultants with prior experience in the qualification of Class 1E equipment are included to provide overall guidance to the laboratory. They will report to the Deputy Director.

The staff will be built up in steps as required to initiate formation of the laboratory and putting it into full-scale operation. The number of laboratory staff employees in each job classification is summarized in Table 4-2 along with an annual budget for salaries. For convenience, salaries were determined on the basis of GS equivalent grades and salary rates effective October 8, 1978. A 100% overhead rate was used in computing the annual budget for salaries. (Overhead encompasses items such as employee benefits, travel, education and sick leave.) The total annual cost for employee salaries, including overhead, was estimated as $3,217,712.

During the startup phase and a subsequent 1-year period, a consulting agreement will be entered into with an independent laboratory experienced in qualification testing of Class 1E equipment. This firm will provide technical support to the laboratory. The annual cost of a consulting contract, including two full-time consultants, was estimated as $225,000.

The office furniture required for the staff totals an estimated $97,300.

4.3.2.5 Phase I Costs Summary

The capital investment necessary for designing, constructing, and equipping a qualification laboratory that meets the requirements of the sequential mode of operation defined for Phase I was estimated as $8,655,000. The time needed to produce the fully equipped laboratory, ready for checkout, was estimated as over 4 years. The capital costs are summarized in Table 4-3. To the designing, constructing, and equipping costs must be added the costs of the 6-month checkout period needed to bring the laboratory to operational status.

Table 4-2

Alternative 1, Phase I, Full Complement
Staffing and Salaries
(From Table 10-2, Appendix B)

Table 10-2. Annual Salaries

Title	Grade	Annual Salary ($)	No. of Employees at Grade	Total Cost per Grade ($)
Laboratory Director	GS-16 Step 3	47,500	1	47,500
Deputy Director	GS-15 Step 1	38,160	1	38,160
Assistant Director	GS-14 Step 1	32,442	3	162,208
Manager	GS-13 Step 1	27,453	7	192,171
Engineer	GS-12 Step 1	23,087	3	69,261
Engineer	GS-11 Step 1	19,263	4	77,052
Engineer	GS-9 Step 1	15,920	4	63,680
Nurse	GS-9 Step 1	15,920	1	15,920
Engineer	GS-7 Step 1	13,014	4	52,056
Supervisor	GS-6 Step 1	11,712	14	163,968
Technician	GS-5 Step 1	10,507	22	231,154
Draftsperson	GS-5 Step 1	10,507	2	21,014
Inspector	GS-5 Step 1	10,507	1	10,507
Secretary	GS-3 Step 1	8,366	13	108,758
Receptionist	GS-3 Step 1	8,366	1	8,366
Switchboard Operator	GS-3 Step 1	8,366	1	8,366
Machinist	GS-3 Step 1	8,366	4	33,464
Vehicle Driver	GS-3 Step 1	8,366	3	25,098
Forklift Operator	GS-3 Step 1	8,366	2	16,732
Maintenance	GS-2 Step 1	7,422	6	44,532
Guard	GS-2 Step 1	7,422	10	74,220
Helper	GS-2 Step 1	7,422	8	59,376
Clerk	GS-1 Step 1	6,561	13	85,293
		Total	127	$1,608,856

Total @ 100% Overhead ~ $3,218,000

Table 4-3

Phase I Capital Costs for Design, Construction and Equipping of Laboratory

Item	Approximate Cost ($1000)
I. Specifications	
Building	300
Test Equipment	450
II. Building Construction Costs	
Building	3,390
III. Test Facilities Equipment	
Thermal Aging Facility	
Oven (3 ft by 3 ft by 4 ft high)	4
Oven (6 ft by 6 ft by 10 ft high)	20
Vibration Facility	
Two vibration tables	11
Two exciter controls	25
Reinforced foundation and isolation mount	15
Irradiation Facility	
Two hot cells	850
Six cobalt-60 sources	1,500
One 30-ton crane with 20-ft span	51
HELB Facility	
Two pressure vessels	54
Steam generator	48
Steam superheater	90
Structural Test Facility	
Steel I-beams	10
Electrical Test Area	
Water immersion tank	5
Dielectric strength test set	15
Schering bridge	15

Table 4-3 (cont)

Item	Approximate Cost ($1000)
Test Control and Data Acquisition Center	
Instrumentation	68
Computer (comp. to CDC Cyber 171)	1,000
Special Handling Equipment	
One 10-ton crane with 20-ft span	29
One 30-ton crane with 45-ft span	60
Support Laboratory	300
Machine Shop	134
IV. Service Facilities Equipment	
Mailroom	4
Receiving/shipping	4
Photography laboratory	13
Publications and print shop	47
Building services	20
Dispensary	3
Cafeteria	23
V. Office Furnishings	97
	Total $8,655

Checkout costs are detailed in the first column of cost data in Table 4-4, where the total estimated checkout cost is shown to be $2,248,000. During the checkout period, costs incurred through use of the test facility will be smaller than those expected during full-scale operation.

The total estimated capital investment is $10,903,000, and the total time to reach operational status is 4-1/2 years.

Table 4-4

Checkout and Operating Budgets for Phase I ($K)

	Cap. Costs	← Operating Costs →					
	Checkout	Testing of Specimen Backlog (4 Years)				Follow-on (1-1/2 Yrs)	
Item	First Six Months	Second Six Months	Second Year	Third Year	Fourth Year	Fifth Year	Sixth Year
Staff Costs							
Salaries	1,609	1,609	3,540	3,894	4,283	4,711	5,183
Consultants	112	113	75	40	40	40	40
Raw Materials							
Metals	10	10	22	24	27	15	16
Wood	2	3	6	7	8	4	4
Building Supplies							
Electrical	10	15	28	30	33	36	40
Plumbing, cleaning, and paint supplies	10	15	27	30	33	37	40
Laboratory Supplies							
Chemicals	3	3	7	8	4	5	6
Nitrogen	1	-	1	1	2	1	1
Office Supplies	5	10	22	24	27	29	32
Services							
Heating (Fuel Oil)	5	5	12	13	14	15	17
Electricity	38	76	167	184	202	167	184
Telephone	21	30	66	73	80	98	97
Mailing	6	13	28	30	33	37	40
Shipping	-	50	110	121	133	73	81
Cleaning	12	13	27	30	33	37	40
Maintenance							
HVAC maintenance	20	20	44	48	53	59	64
Replacement equip.	5	5	11	12	13	14	16
Copying Machines*	4	5	11	12	13	11	9
Radiation Source	375	375	825	908	1,000	1,100	1,210
Total	2,248	2,370	5,029†	5,489†	6,031†	6,489†	7,120†

Notes: * Cost includes purchase price amortized over five years.
† Cost reflects a 10% increase over the previous year to account for inflation.

Operating costs for the 5-1/2 years following the construction/checkout stage are summarized in Table 4-4. Four years are scheduled for completion of qualification tests on the entire backlog of Class 1E specimens; during the last 1-1/2 years, the testing effort will be decreased gradually, and research and development work will be undertaken.

4.3.3 Phase II

4.3.3.1 General Guidelines

The basic objective of the Phase II analysis was to decrease the time required to complete the testing of the entire backlog of 135 Class 1E specimens. An outcome of the Phase I analysis of a minimally equipped laboratory was that 4 years would be required to test the backlog of specimens in an essentially sequential mode. Based on this outcome and considerations of practical limits on the size of a qualification laboratory and the staff that can be recruited, it was decided that the Phase II laboratory should be equipped to process the backlog of specimens within 1-1/2 years. This was to be accomplished by equipping the laboratory with multiple units of each type of test facility and processing the specimens in a parallel mode.

The Phase II testing period of 1-1/2 years was considered to be a practical limit to which the 4-year period of Phase I could be reduced. Further reduction would aggravate the problem of recruiting a qualified staff and putting the laboratory into operation fast enough to meet the specified schedule. It would also severely complicate the logistics of bringing the specimens into the laboratory and processing them on schedule, and any deviation from the schedule would have more critical consequences.

4.3.3.2 Test Facilities, Laboratories, and Services

The test equipment necessary to support the Phase II operation is identical to that specified for Phase I, and is listed in Table 4-5. The number of sets of thermal aging ovens, vibration tables, HELB test vessels, and structural and electrical test facilities was quadrupled to support Phase II operations. Since superheated steam is required only for the first 1/2-hour of the 30-day HELE exposure, 2 superheaters are adequate for supplying superheated steam to the 8 HELB vessels. The two hot cells provided in the gamma irradiation facility of Phase I suffice for Phase II. The amount of instrumentation and control equipment was increased in proportion to the increase in the number of each type of test facility.

The same support laboratories and machine shop will be provided for Phase II as those described for the Phase I program. However, the laboratories will be equipped with more scientific apparatus to meet the requirements of the greater work load anticipated for Phase II. The amount budgeted for its acquisition for Phase II operations was $325,000. The tools for equipping the machine shop in Phase I are adequate for Phase II also.

The facilities for providing functional services, such as communications and printing, are identical in Phase II to those described for Phase I.

4.3.3.3 Buildings and Layouts

The laboratory building designed for Phase II operations will be a single-level structure constructed of concrete and brick with a high-bay ceiling over the test laboratory. The facility will have 160,000 ft^2 of floor space, of which 52,400 ft^2 will be allotted for office space, 104,000 ft^2 for the test laboratory, and 3,600 ft^2 for the irradiation facility. The building layout is illustrated in Figure 4-4.

The total cost of constructing the proposed 160,000-ft^2 laboratory building, including the test laboratory, irradiation facility (minus the hot cells) and offices, was estimated as $9,600,000, based on the previous $60/$ft^2$ value.

4.3.3.4 Staffing and Organization and Staff Costs

An organization chart and staffing level for the Phase II laboratory are presented in Figure 4-5.

Table 4-5

Phase II Test Facilities

Function	Facility	Est. Floor Space Req'd (ft^2)	Est. Cost ($)
1. Thermal aging	Four 3-ft by 3-ft by 4-ft-high ovens	400	16,800
	Four 6-ft by 6-ft by 10-ft-high ovens	800	80,000
2. Vibrational aging	Four 8-in-diam vibration tables	200	2,000
	Four 6-ft by 10-ft vibration tables	400	40,000
	Eight exciter controls	N/A	98,000
3. Gamma irradiation	Two hot cells	3,600	850,000
	Six cobalt-60 sources	N/A	1,500,000
	One 30-ton crane with 20-ft span	N/A	50,500 (installed)
4. HELB exposure	Four 3-ft-diam by 4-ft-high pressure vessels	800	72,000
	Four 6-ft-diam by 10-ft-high pressure vessels	1,600	144,000
	One 200-bhp steam generator	250	47,500
	Two 200-kW steam superheaters	200	180,000
5. Structural tests (force tests)	Four steel I-beams ("strong-back")	800	40,000
6. Electrical tests (functional tests, operational aging, and cable electrical property tests)	High-voltage power supply	200	N/A
	Low-voltage power supply	200	N/A
	Four water immersion tanks	2,000	20,000
	Four dielectric strength tests	400	60,000
	Four Schering bridges	400	60,000
7. Test control and data acquisition center	Data acquisition instruments	4,000	231,000
	Computer (comparable to a CDC Cyber 171)	500	1,000,000
8. Special handling equipment	One 10-ton crane with 20-ft span	N/A	29,000 (installed)
	One 30-ton crane with 45-ft span	N/A	59,500 (installed)
		Total	4,580,300

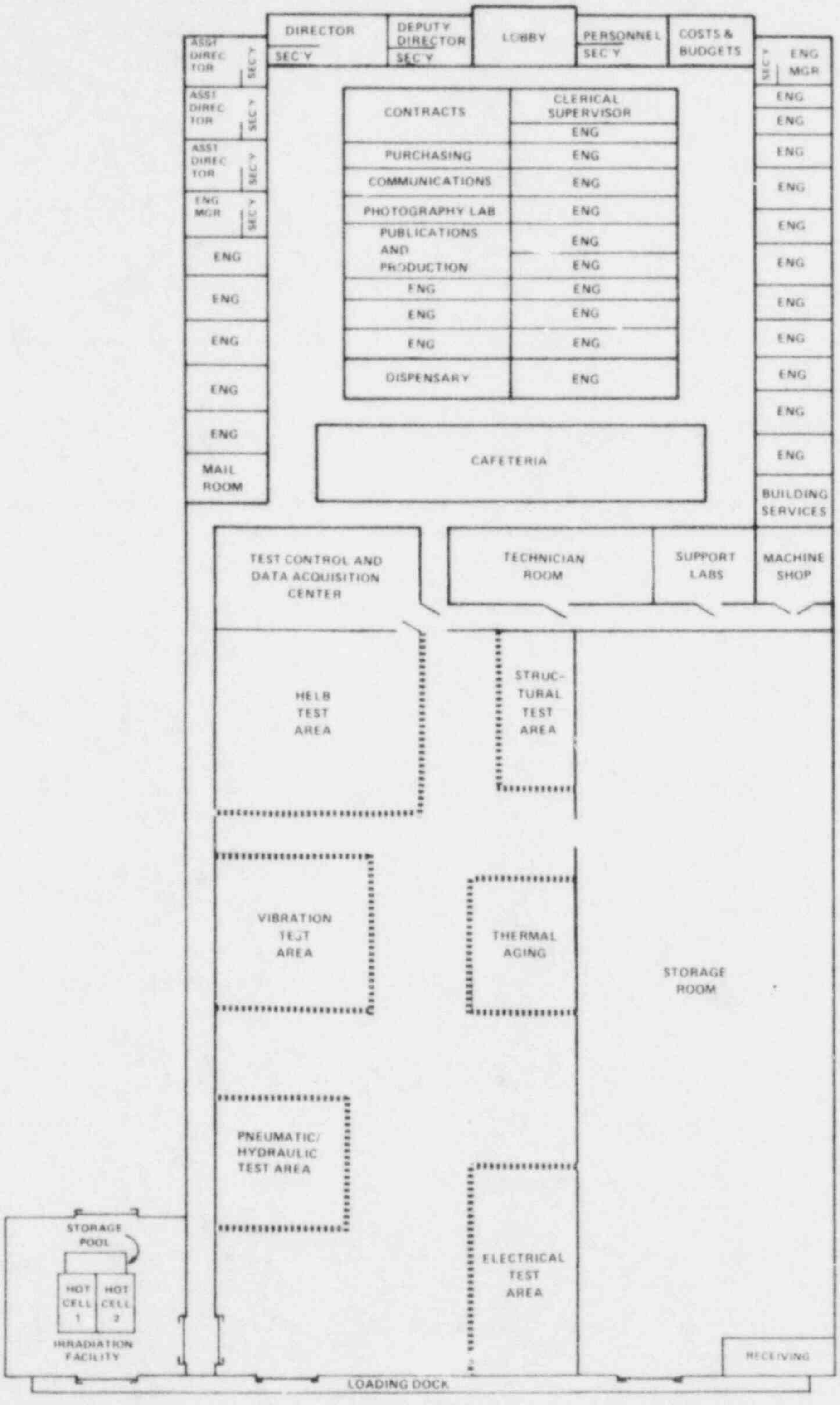


Figure 4-4 Layout of Phase II Qualification Laboratory

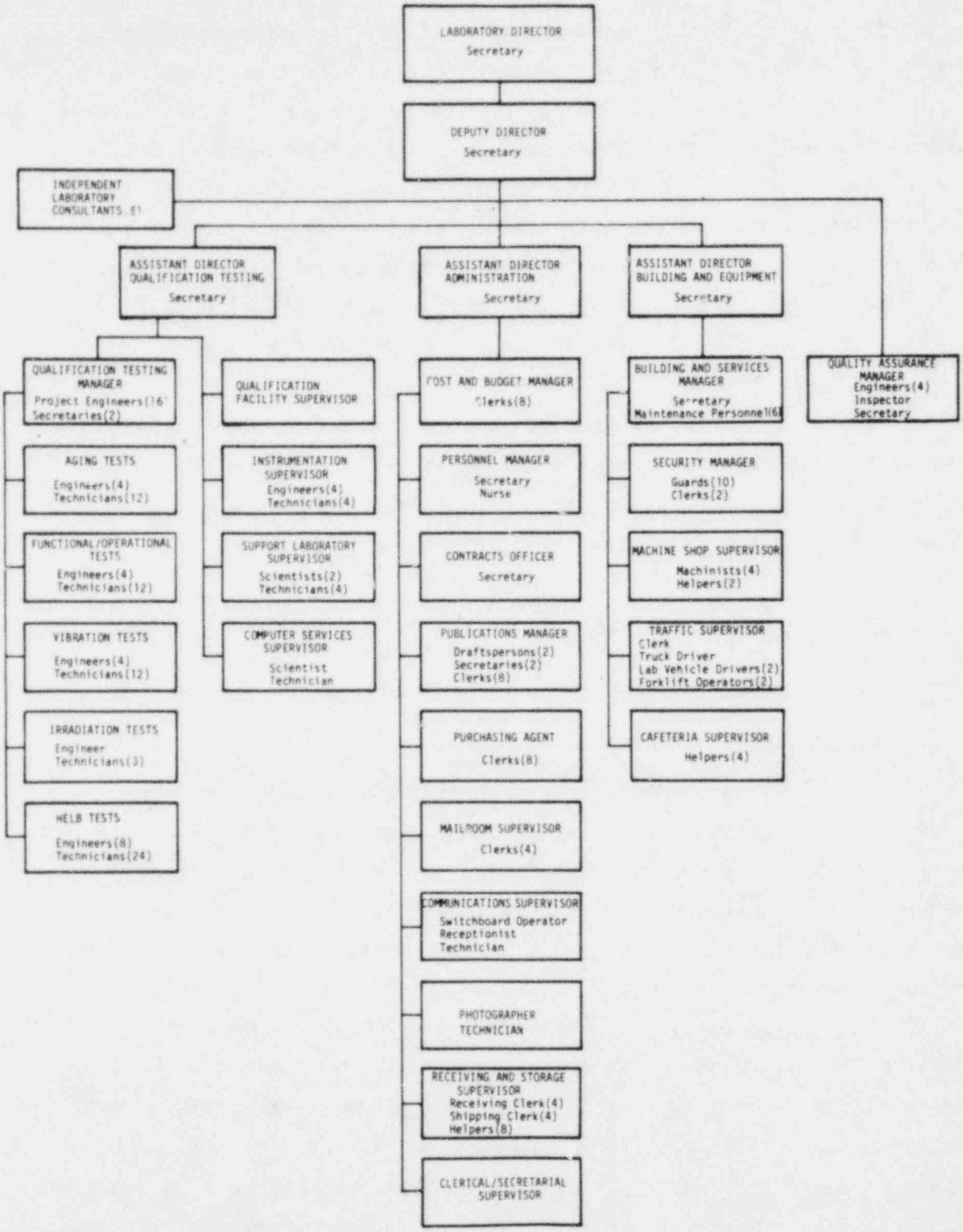


Figure 4-5 Organization Chart and Staffing Level for Phase II Qualification Laboratory

The management organization of the Laboratory for Phase II operations is identical to that planned for Phase I, and the responsibilities and functions of the directors and managers are identical to those described for Phase I. There will be no increase in the number of management personnel. However, Phase II operations will require an increase in the engineering and technical staff proposed for Phase I to support the additional test work load. The number of employees proposed for each labor category is summarized in Table 4-6 along with an annual budget for salaries. A 100% overhead rate was used in computing the annual budget for salaries. The total annual cost for staff was estimated as $5,845,630.

A consulting company experienced in qualification testing will be engaged by the laboratory to provide technical support during the initial period of operation. Four engineering consultants and a supervisor will be placed under contract at a cost of $250,000/year.

The cost of staff office furnishings for Phase II operations was estimated as $130,100.

4.3.3.5 Phase II Costs Summary

The capital investment necessary for designing, constructing, and equipping a qualification laboratory that meets the requirements of the parallel mode of operation defined for Phase II was estimated as $15,686,000. The capital costs are detailed in Table 4-7. The time needed to produce the fully equipped laboratory, ready for checkout, was estimated as 4 years.

To the designing, constructing, and equipping costs must be added the costs of the 6-month checkout period needed to bring the laboratory to operational status. Checkout costs are detailed in the first column of cost data in Table 4-8, where the total estimated checkout cost is shown to be $3,886,000. The total estimated capital investment is $19,572,000, and the total time to reach operational status is 4-1/2 years.

Table 4-6

Alternative 1, Phase II, Full Complement
Staffing and Salaries
(From Table 13-4, Appendix B)

Title	Grade	Annual Salary ($)	No. of Employees at Grade	Total Cost Per Grade ($)
Director	GS-16 Step 3	47,500	1	47,500
Deputy Director	GS-15 Step 1	38,160	1	38,160
Assistant Director	GS-14 Step 1	32,442	3	97,326
Manager	GS-13 Step 1	27,453	7	192,171
Engineer	GS-12 Step 1	23,087	12	277,044
Engineer	GS-11 Step 1	19,263	12	231,156
Engineer	GS-9 Step 1	15,920	12	191,040
Nurse	GS-9 Step 1	15,920	1	15,920
Engineer	GS-7 Step 1	13,014	12	156,168
Supervisor	GS-6 Step 1	11,712	14	163,968
Technician	GS-5 Step 1	10,507	74	777,518
Draftsperson	GS-5 Step 1	10,507	2	21,014
Inspector	GS-5 Step 1	10,507	1	10,507
Secretary	GS-3 Step 1	8,366	13	108,758
Receptionist	GS-3 Step 1	8,366	1	8,366
Switchboard Operator	GS-3 Step 1	8,366	1	8,366
Machinist	GS-3 Step 1	8,366	4	33,464
Vehicle Driver	GS-3 Step 1	8,366	3	25,098
Forklift Operator	GS-3 Step 1	8,366	2	16,732
Maintenance	GS-2 Step 1	7,422	6	44,532
Guard	GS-2 Step 1	7,422	10	74,220
Helper	GS-2 Step 1	7,422	14	133,908
Clerk	GS-1 Step 1	6,561	39	249,879
		Total	245	$2,922,815

Total @ 100% Overhead $5,846,000

Table 4-7

Phase II Capital Costs for the Design, Construction and Equipping of Laboratory

Item	Approximate Cost ($1000)
I. Specifications	
Building	300
Test Equipment	450
II. Building Construction Costs	
Building	9,600
III. Test Facilities Equipment	
Eight circulating-air ovens	97
Vibration Facility	
Eight vibration tables	42
Eight exciter controls	98
Reinforced foundation and isolation mount	60
Irradiation Facility	
Two hot cells	850
Six cobalt-60 sources	1,500
One 30-ton crane with 20-ft span	50
HELB Facility	
Eight pressure vessels	216
Steam generator	48
Two steam superheaters	180
Structural Test Facility	
Four steel I-beams	40

Table 4-7 (cont)

Item	Approximate Cost ($1000)
Electrical Test Area	
Four water immersion tanks	20
Four dielectric strength test sets	60
Four Schering bridges	60
Test Control and Data Acquisition Center	
Instrumentation	231
Computer (comp. to CDC Cyber 171)	1,000
Special Handling Equipment	
One 10-ton crane with 20-ft span	29
One 30-ton crane with 45-ft span	60
Support Laboratory	325
Machine Shop	134
IV. Service Facilities Equipment	
Mailroom	4
Receiving/shipping	4
Photography laboratory	13
Publications and print shop	47
Building services	20
Dispensary	3
Cafeteria	14
V. Office Furnishings	131
Total	15,686

Table 4-8

Checkout and Operating Budgets for Phase II ($K)

	Cap. Costs	Operating Costs			
	Checkout	Testing of Specimen Backlog (1-1/2 yrs)		Follow-on Effort (2 yrs)	
Item	First Six Months	Second Six Months	Second Year†	Third Year†	Fourth Year†
Staff Costs					
Salaries	2,923	2,923	6,430	7,033	7,780
Consultants	125	125	83	42	42
Raw Materials					
Metals	20	40	88	97	107
Wood	2	10	20	22	24
Building Supplies					
Electrical	10	35	77	85	93
Plumbing, cleaning and paint supplies	35	35	77	85	93
Laboratories Supplies					
Chemicals	2	15	30	33	36
Nitrogen	2	2	4	4	5
Office Supplies	20	20	44	48	53
Services					
Heating (Fuel Oil)	16	16	34	38	42
Electricity	150	300	660	726	800
Telephone	66	66	132	145	160
Mailing	24	24	53	58	64
Shipping	5	20	44	48	53
Cleaning	25	25	55	60	66
Maintenance					
HVAC maintenance	61	61	134	148	163
Replacement equipment	20	20	44	48	53
Copying Machines*	5	5	11	12	13
Radiation Source	375	375	825	908	998
Total	3,886	4,117	8,845	9,680	10,645

*Cost includes purchase price amortized over five years.
†Cost reflects a 10% increase over the previous year to account for inflation.

The operating costs for the 3-1/2 years following the construction/checkout stage are summarized in Table 4-8. One and one-half years are scheduled for completion of qualification tests on the entire backlog of Class 1E specimens; during the last 2 years, the testing effort will be decreased gradually, and research and development work will be undertaken.

4.4 Other Considerations and the Completed Alternative

The test facility, as outlined, will perform its function when it is fully operational. But other considerations need to be addressed to complete the scope implied under Alternative 1. Three separate issues can be identified: Facility Design, Construction, and Checkout; Purchases and Costs of Test Specimens; and Post-Backlog Facility Uses.

4.4.1 Facility Design, Construction, and Checkout

Clearly, the facility is not instantly available to perform qualification verification tests. From formal commitments to proceed with the program, the sequence requires: procurement and scoping specifications; architect-engineering (AE) specifications; bidding and review; construction; staffing and training; equipment specification and procurement; and facility shakedown. Another (potentially delaying) factor, unique to government-sponsored construction programs of this magnitude, is that normally it would be included as a line-item budget request from Congress; hence, it would be subject to budget timing delays and Congressional review/modification. It is not possible to anticipate budget review and timing beyond generally recognizing it as a negative and delaying factor. It can be assumed that with a mandate to proceed, funding could be made available from discretionary sources to begin the planning, at least up to the point of soliciting construction bids.

Table 4-9 outlines the major efforts, milestones, and timing leading to a fully operational test facility (Appendix B also has relevant discussion). The timing is neither a minimum nor a maximum, but intended to be somewhat realistic. While the tasks and timing are individually arguable, the total time is accurate within a year or two. Then the 4-year 9-month period to achieve operational status is a formidable obstacle to the alternative as a "timely" workable solution. Some key assumptions in this table deserve additional amplification.

Table 4-9

Alternative 1 - The Formative Stages

NRC supplies 4 FTE staff

NRC staff prepares master contract to designate ultimate facility operator

NRC staff selects, obtains facility site on existing reservation

Operator selected

Facility site acquired

Operator supplies 4 FTE staff; one should be ultimate facility manager; 10 FTE at year-end

Operator prepares procurement, scoping specifications for AE use, bid, etc

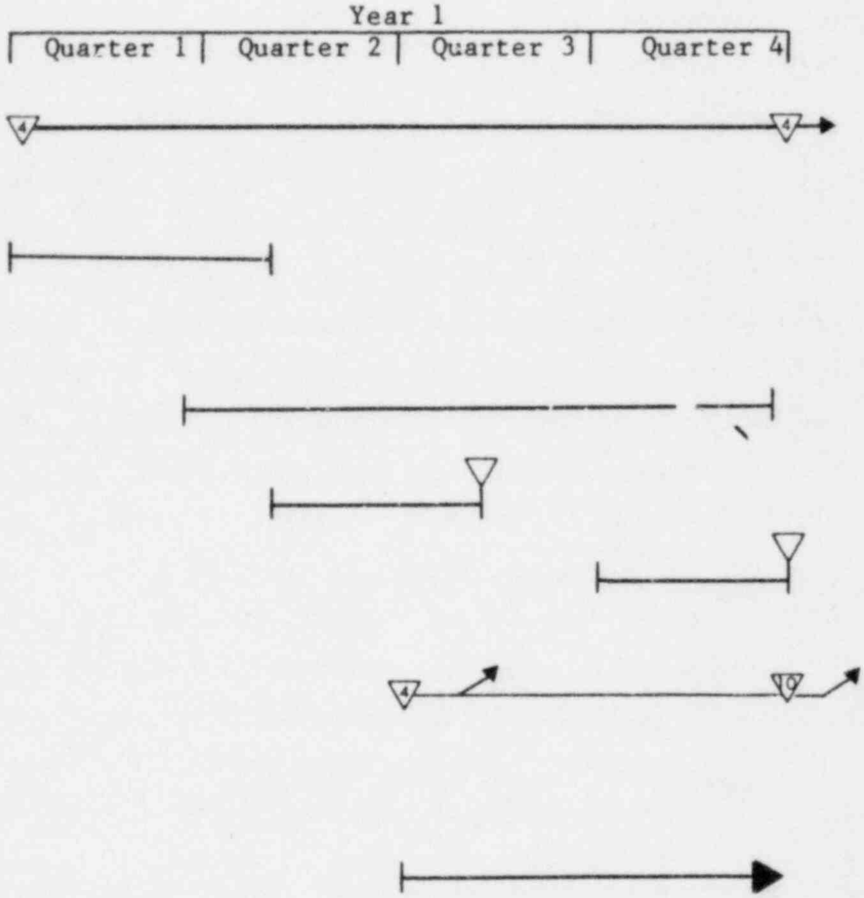


Table 4-9 (cont)

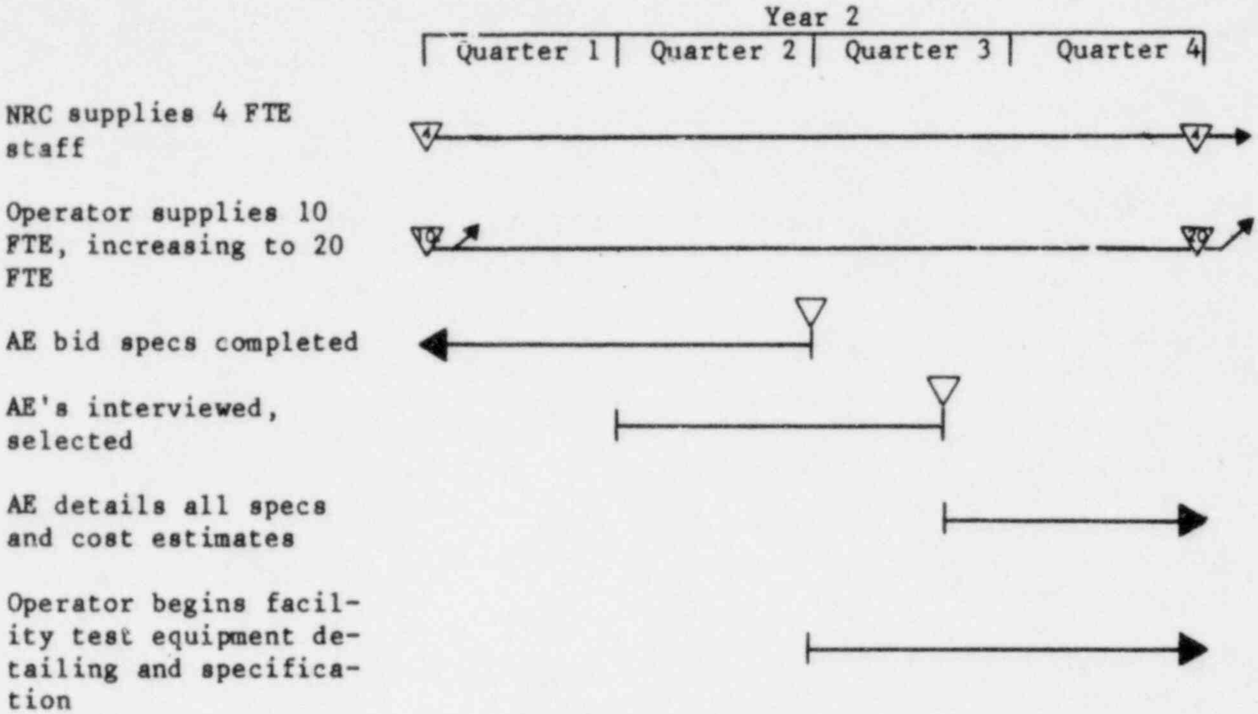


Table 4-9 (cont)

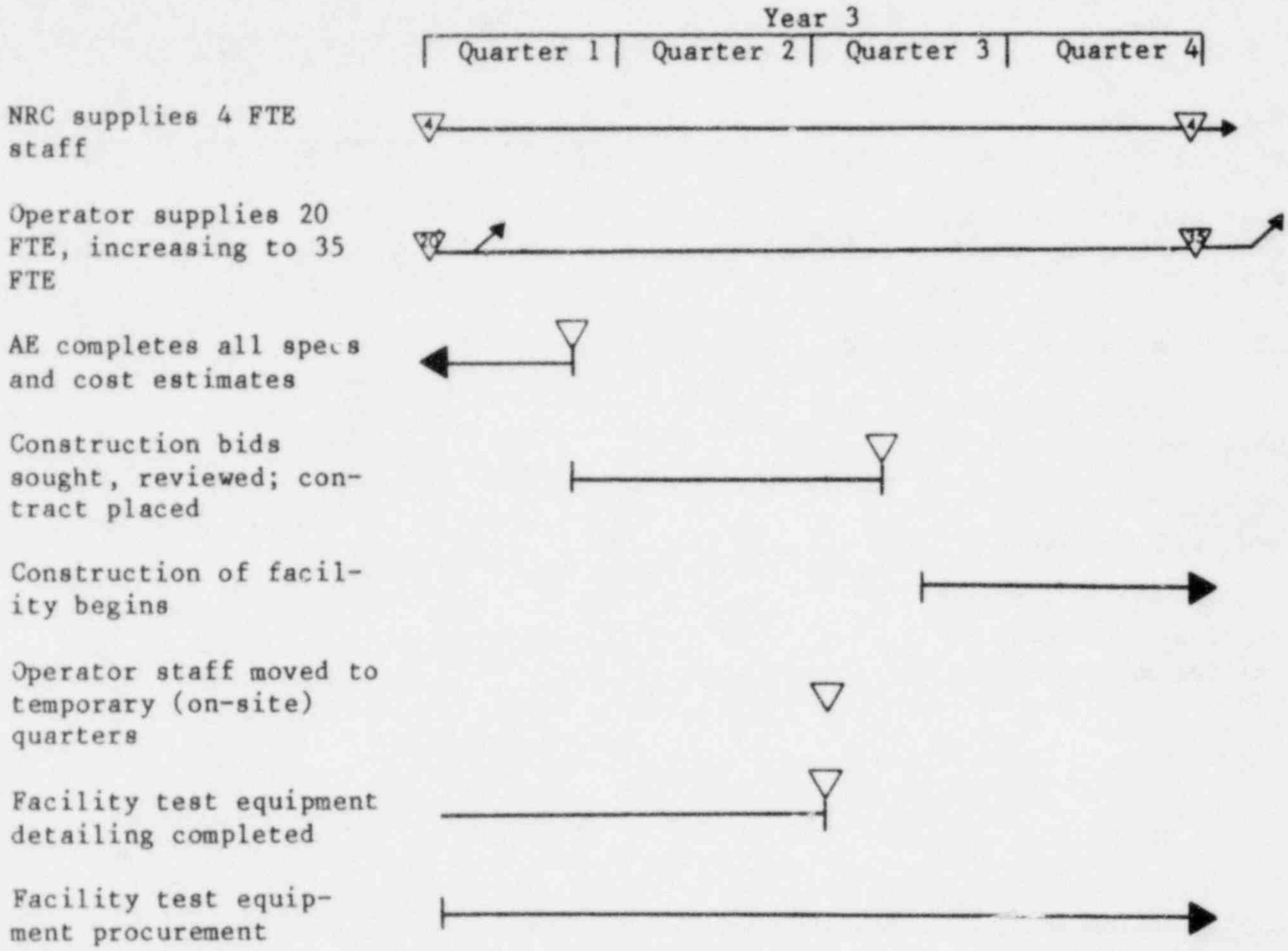


Table 4-9 (cont)

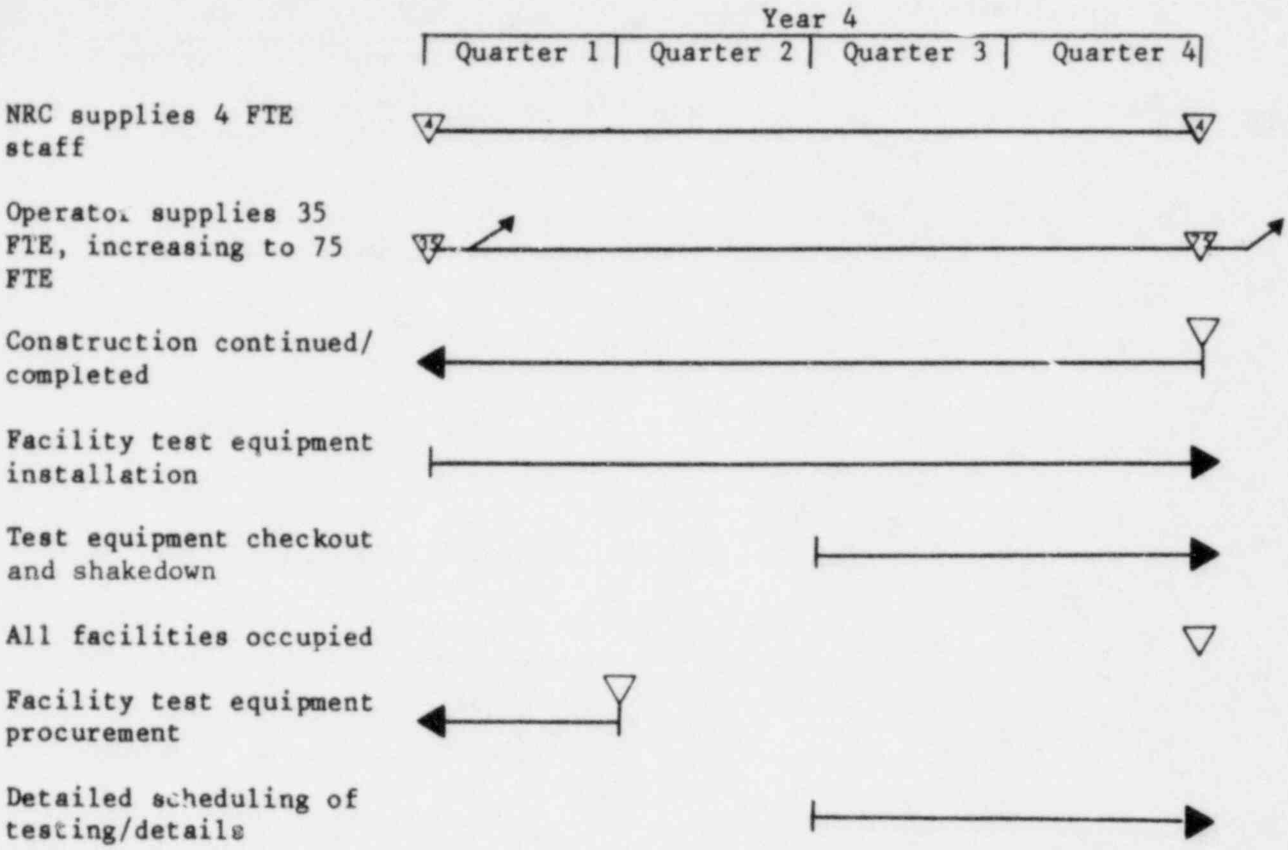
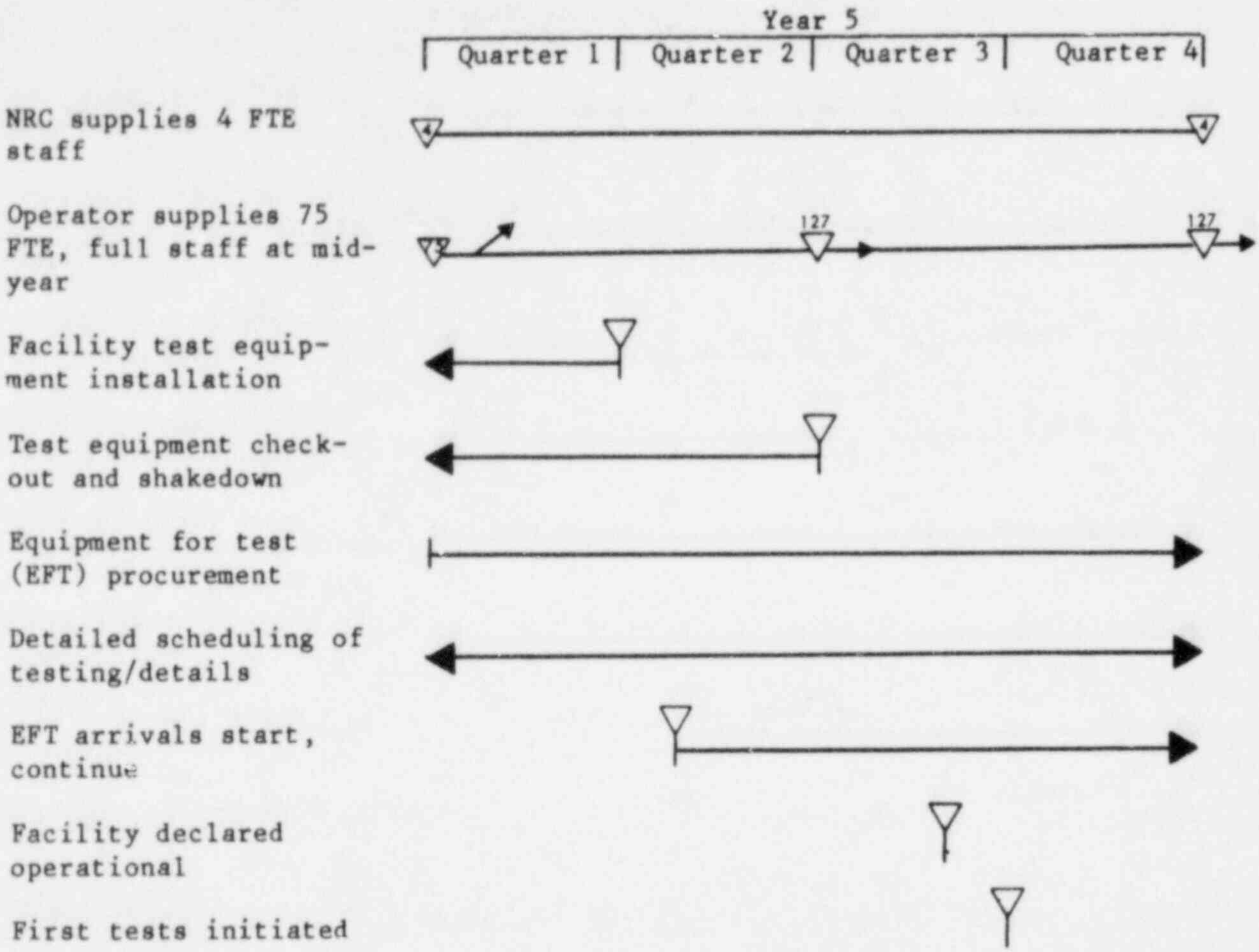


Table 4-9 (cont)



The project will require full-time and direct NRC support, at least at a full branch-equivalent level. Four FTE (full-time equivalent) staff are recommended here; total miscellaneous staffing would be greater to accomplish necessary reviews and decision making. (This latter category could exceed 10 FTE, and is considered indirect cost in this writeup.) The first year activities would concentrate on facility-operator and site selection. The subsequent years, during facility construction, would be spent in financial programming, NRC/operator liaison, and planning reviews/ decisions. After construction and during full operation, the NRC-staff work would expand to accomplish the role of direct NRC involvement in the verification tests.

The level-of-effort entailed by the facility and its operation virtually demands the services of a contractor. It is also recommended that the contractor have existing experience and facilities; the site selection should coincide with that of the contractor location to the maximum extent practicable. With existing facilities, necessary support services (e.g., secretarial, office space, purchasing) can be immediately obtained at the (fluctuating) levels that may be required. Additional delays are implied if a new contractor and/or site are chosen.

Staffing by the operator should follow a consistent pattern. Experienced (qualification) engineers would make up the majority of the staff in the first years; the earliest selected staff would include the ultimate manager of the operational facility to assure continuity and outlook. In later years, more of the support personnel would be selected (hence, the reduction in the FTE man-year charge estimate). The staff would be selected to affect smooth transition from the construction to the operation phase without significant personnel turnover.

To summarize the section, Table 4-10 provides a year-by-year breakdown of the major milestones and staffing costs to achieve facility operational status; the costs for AE assistance, construction and test equipment are separately addressed later. The ultimate staffing reaches 127 people (Table 4-2) for Alternative 1, Phase I; the staff character is illustrated in the table. During the formative stages, the general tenor of the ultimate staffing is retained but at reduced numbers; this is reflected in Table 4-10.

4.4.2 Purchases and Costs of Test Specimens

An added cost associated with this alternative is the necessity to purchase safety-related equipment for the verification tests. UEC provided the cost estimates for this equipment, as previously discussed in Section 4.2. Table 4-11 summarizes and totals these costs and are excerpted from Appendix A. Inherent in the table is the assumption that no duplication, or repeat, of any test is needed (because of test equipment failure, "interesting" results requiring follow on tests, etc) and hence no additional equipment and cost.

The cost of in-containment equipment (one of each type) totals about $700K, but some 70% of that total is due to four control and four instrumentation penetrations at $60K each. The ex-containment equipment totals about $420K, with 60% of that required for the purchase of five radiation monitoring systems at $50K each. The total cost of all equipment is $1116K; but if these three generic items are excluded, the total is a more modest $386K

4.4.3 The Testing Period

Alternative 1, Phase I, will require a 4-year testing duration to complete the equipment backlog beginning about the middle to end of year 5. Table 4-12 summarizes the funding schedule leading to the completion of that backlog. The testing period is relatively straightforward, given the staff and developed facility; little additional explanation is necessary.

4.4.4 "Post-Backlog" Facility Uses

Once the equipment verification tests backlog is completed, a multi-million dollar capital facility, with 125+ staff and a $8M+ annual budget, remains. Clearly, this is not a "throw-away" facility, and long-term uses must be identified before this alternative has much potential of being given serious consideration.

Table 4-10

Alternative 1, Phase I, Milestones and Costs - The Formative Stages

During Year	Major Milestones	Direct NRC Cost (4 FTE) (K$)	Indirect NRC Cost (to 10 FTE at year 5 and beyond) (K$)	Facility Staff Operation Cost (K$)
1	Operator selected; Site selected	200	50 (1 FTE)	200
2	AE bid specs complete; AE selected	220	170 (3 FTE)	900
3	AE completes all specs; constructor selected; construction begins; test equipment detailed	250	300 (5 FTE)	1400
4	Facility construction complete; facility fully occupied; all test equipment ordered	275	560 (8 FTE)	2200
5	All test equipment installed; facility shakedown complete; facility declared operational; first backlog tests initiated	325	800 (10 FTE)	3218
		1270	1880	7718

Table 4-11

Costs of Safety-Related Equipment

Generic Equipment Category	Number of Manufacturers	Total Types to Test	Cost per Item ($)	Total Generic Equipment Cost ($)
	IN-CONTAINMENT			
Transmitters	4	11	2K	22K
Electric actuators	2	5	3K	15K
Pneumatic actuators	5	7	1.5K	10.5K
Thermocouples	4	6	500	3K
RTD	5	4	2K	8K
Limit switch	2	4	200	800
Differential Pressure Switch	4	6	1.5K	9K
Pressure switch	5	5	300	1.5K
Solenoid valves	5	5	1.2K	6K
Terminal blocks	4	5	40	200
Enclosure	1	1	800	800
Radiation monitoring system (Area)	3	3	2.5K	7.5K
Terminal lugs	2	3	1K 100 1K	2.1K
300-V instrument cable	4	4	200	800
300-V thermocouple cable	4	4	200	800
600-V control cable (2C/# 14)	4	4	200	800
Motors (460-V)	4	6	5K	30K
Power penetrations	4	4	15K	60K
Control penetrations	4	4	60K	240K

Table 4-11 (cont)

Generic Equipment Category	Number of Manufacturers	Total Types to Test	Cost per Item ($)	Total Generic Equipment Cost ($)
Instrumentation penetrations	4	4	60K	240K
600-V power cable (3C/# 12)	5	4	400	1.6K
600-V power cable (3C/250 MCM)	5	4	4K	1.6K
Connectors	6	6	300	1.8K
Rotometers	2	2	7.5K	15K
Level switch	2	4	900	3.6K
Splices	1	5	50	250
		Total (In-Containment) =		697,050
EX-CONTAINMENT AND SPECIAL				
Radiation monitoring system (airborne, etc)	3	5	50K	250K
Hydrogen analyzer	4	3	8K	24K
5-kV cable (3C, 4/o)	4	4	2K	8K
5-kV cable (3C/350 MCM)	4	4	8K	32K
Motors (4 kV)	3	3	15K	45K
Switchboard wire	1	1	60	60
Neutron monitors	4	4	15K	60K
	Total (Ex-Containment and Special) =			419,060
		Total (In-Containment) =		697,050
			TOTAL =	1,116,110

Table 4-12

Alternative 1, Phase I, Funding Schedule (K$)

	Year 1	2	3	4	5	6	7	8	9	Annual Follow-On
Direct NRC staff (4 FTE)	200	220	250	275	325	375	425	500	575	650
Facility staff	200	900	1400	2200	3450	3600	3925	4325	4750	5225
AE/construction/equipping	250	500	1600	5000	--	--	--	--	--	--
Equipment costs	--	--	200	800	116	200	220	250	275	300
Facility maintenance	--	--	--	--	593	988	1110	1225	1165	1847
Yearly	650	1620	3450	8275	4484	5163	5680	6300	6765	8022
Cumulative	650	2270	5720	13,995	18,479	23,642	29,322	35,632	42,397	50,419
					← ~4 year testing (years 5–9) →					
Additional Indirect NRC Staff (to 10 FTE at year 5 and beyond)	50	170	300	560	800	880	970	1075	1200	1400

Two immediate uses should be considered. First, a continuing stream of new or modified equipment will require qualification verification tests. And/or new test profiles may emerge which could require retesting of previously tested equipment.

Secondly, the facility should be ideal for evaluating qualification testing methodologies and general research applications. Each test sequence has potential for research: thermal aging, radiation application, vibration, operational cycling, and LOCA-simulation. In addition, research into extensions of the state-of-the-art are also appropriate. It is not within the scope of this report to thoroughly examine these areas. But it should be noted (from Appendix B) that about two-thirds of the estimated annual operating costs is for staff; the estimated level of long-term use and the yearly cost are certainly adjustable.

4.4.5 Alternative 1, Phase II Summary

Phase II allows earlier completion of the equipment backlog testing through use of increased staff and test facility capacity. Table 4-6 summarizes the full-complement staffing. Table 4-13 summarizes the funding schedule leading to completion of the backlog.

4.5 Evaluation of Alternative 1, Phase I, Against the Criteria

Before detailed discussion of each criterion, Table 4-14 summarizes the scoring of the alternative; justification of the selected scoring is given in the evaluation writeups below. Section 4.6 continues the criteria evaluations but with regard to a quasi cost/benefit format and with some discussion of relative basis importances. Criterion with an asterisk (*) indicates a "core" criterion as described in Section 3.4.2.

Table 4-13

Alternative 1, Phase II, Funding Schedule (K$)

	Year						Annual Followon Year	
	1	2	3	4	5	6	7	8
Direct NRC staff (4 FTE)	200	220	250	275	325	375	475	500
Facility staff	200	1200	2500	4500	6100	6500	7100	7800
AE/construction/equipping	250	250	4800	8900	--	--	--	--
Equipment costs	--	--	200	800	116	200	220	250
Facility maintenance	--	--	--	--	1441	1748	1922	2145
Yearly	650	1670	7750	14,475	7982	8823	9667	10,695
Cumulative	650	2320	10,070	24,545	32,527	41,350	51,017	61,712
					←~18 month testing→			
Additional Indirect NRC Staff (to 10 FTE at Year 5 and beyond)	50	170	300	560	800	880	970	1075

Table 4-14

Alternative 1, Phase I, Scoring

Criterion	Description	Score*
1	Level of NRC Involvement	9
2	"Immediacy" of the Alternative	2
3	Costs: Initial, Yearly, Long-Term	3
4	Direct Control of Prior-Tests Verifications	8
5	Flexibility	9
6	Degree of Control Available	9
7	Long-Term Use Potential	8
8	Staffing Levels Required from NRC to Implement Alternative	7
9	Historical/Chartered Function of the NRC	3
10	Dependence on the Supplier/Vendor	4
11	Conflict-of-Interest/Conflict-of-Participants-Interest	8
	Total Score	70

*1 -- most negative
5 -- neutral
9 -- most positive

4.5.1 Individual Criterion Discussion

(*) Criterion 1: Level of NRC Involvement: Whether the dedicated test facility is owned directly or exclusively controlled by NRC, clearly, Alternative 1 offers the ultimate for direct NRC involvement in qualification verification testing. Its selection as one of the three alternatives for detailed study is due, in part, to this a'priori recognized factor. The score is 9.

(*) Criterion 2: "Immediacy" of the Alternative: In contrast to the highly positive factor for NRC involvement, Alternative 1 is difficult, costly, and particularly, time-consuming to implement. Ignoring the potential frustrations associated with line-item Congressional budget entries, the Section 4.4.1 analysis indicates a delay duration of almost 5 years from NRC commitment to first test results. Since this delay is somewhat dependent upon the priority given to the work, it is conceivable that the delay could be foreshortened and/or the work paralleled to a greater extent. The score is 2, recognizing it as quite negative but avoiding the description of it as absolutely intractable.

(*) Criterion 3: Costs; Initial, Yearly, Long-Term: With regard to costs, this alternative suffers in three respects. First, the direct yearly cost associated with the use/maintenance of the facility are high, some $4M+, plus the purchase of test equipment. Second, costs during the design and construction phase grow yearly and are not immediately offset with results. Third, the facility represents a long-term cost commitment competing for funding with other NRC programs/dollars. Yet the $4M+ does not represent a totally unreasonable cost, when compared with other major NRC-budget programs. The score is 3.

Criterion 4: Direct Control of Prior-Tests Verifications: The adaptability of this alternative to respond to questions concerning in-place equipment qualification is obvious. But while the test facility would be available, there could be difficulties in obtaining equipment for test. It is conceivable that a direct NRC order would be necessary, for example, to obtain spare equipment items. For those older equipment items no longer directly available from the manufacturer, other, directly technical, problems in obtaining it are evident. Still Alternative 1 is directly amenable to prior-tested equipment verification; the score is 8.

Criterion 5: Flexibility: Any owned or controlled facility is inherently "flexible." As the needs or bases shift to accommodate new qualification "issues," the dedicated test facility can be immediately directed towards new goals. The only limits to flexibility are the perceived priorities of the goals and the cost factors associated with goal realignment. The score is 9.

Criterion 6: Degree of Control Available: As a subcase of Criterion 5, Alternative 1 clearly offers direct control as an advantage. Such control relaxes the concern for uncertainty of absolute and unchangeable problem definition. That is to say, the criterion offers special flexibility; the score is 9.

Criterion 7: Long-Term Use Potential: It is generally agreed that qualification issues will remain a part of a viable nuclear power industry. On that basis alone, there is a recognized need for a general test facility to continue to evaluate qualification testing methodologies; the dedicated test facility offers such long-term use potential. Conversely, the exact direction of qualification issues cannot be completely anticipated a'priori. It is reasonable to expect that additional capital investment could be necessary to complement any specific eventual facility uses. Reflecting these uncertainties, but with an overall strongly positive factor, the score is 8.

(*) Criterion 8: Staffing Levels Required from NRC to Implement Alternative: Direct NRC manpower necessary to initiate and guide this alternative are low, estimated to be four FTE personnel. Here, direct manpower is to be distinguished from contractor or facility costs as described in Criterion 3. Neither does the four FTE estimate consider other NRC reviewer/management overhead, generally an intangible item and included in the routine NRC function (estimated at 10 FTE in Tables 4-10, 4-12 and 4-13). In general, the lower the direct NRC manpower requirements the greater the (positive) score for this criterion. The score of 7 reflects the strongly positive features of this criterion, while recognizing that some dedicated NRC manpower will need to be diverted to this program to assure its success.

(*) Criterion 9: Historical/Chartered Function of the NRC: Direct involvement in qualification verification tests would be a new experience to the NRC. It is virtually imperative that actual testing be conducted by a captive contract organization to avoid the cumbersome features of civil service, subcontracting restrictions, purchasing, sole-source contracts, etc.

To select Alternative 1 is to realize that all tests and results are directly available to the general public and are subject to scrutiny and interpretation. This will pressure all participants to an even greater degree than that which currently exists. There will be little opportunity to use engineering judgment in the test results or to account for "grey" areas in a normal scientific fashion; i.e., any test result will be viewed as only pass/fail by some interested parties.

Although these tests are not intended to be qualification tests (as distinguished from verification and/or research tests) new licensees may attempt to umbrella their equipment and claim qualification through them. Alternative 1 would then require careful on-going attention to clearly distinguish the dedicated-facility's role and day-to-day use.

Since the factors are essentially negative and since Alternative 1 represents a new course for NRC, the score is 3.

(*) <u>Criterion 10: Dependence on the Supplier/Vendor</u>: The actual conduct of the verification tests depends upon the timely supply of equipment for testing. This implies two separate uncertainties. First, vendor supply of a one-of-a-kind item is normally subject to large delivery schedule slippages and uncertainties. Second, the satisfactory certification that the vendor has supplied the actual "type" to be used in the field is a concern. By way of contrast, this latter concern is lessened where, and if, a test item can be selected directly from a larger order of such equipment; but this implies substantial effort to conduct tests in concert with equipment deliveries to ultimate users and as a result to be somewhat "at the mercy" of these users and vendors.

It is clear that any alternative selected cannot entirely avoid these problems. More than likely, it will be necessary (on occasion) to use implicit, or explicit, legal "clout" to accomplish overall aims and schedules. Alternative 1 does offer some overall flexibility to accommodate the criterion; the score is 4, slightly negative.

(*) Criterion 11: Conflict-of-Interest/Conflict-of-Participants-Interests: An NRC owned, or directly controlled, dedicated test facility substantially precludes conflict-of-interest charges and eliminates any conflict-of-participant-interest concerns. By avoiding subcontracting and subsubcontracting, "at-arms-length" transactions are easier to maintain. Similarly, there is no involvement of contract test labs (i.e., industry) where NRC-industry and industry-client interests are not mutually exclusive and thus jeopardize relationships. Alternative 1 offers minimal concern for this criterion; the score is 8.

4.5.2 Alternative 1 "Scoring" Summary

Alternative 1 is not neutral in its scoring to the criteria; generally the alternative ranks highly positive (Criteria 1, 4, 5, 6, 11) or highly negative (Criteria 2, 3, 9). The total unweighted score is 70 out of a possible 99. It offers as its primary advantages direct NRC involvement, control, and flexibility; conversely, it is costly and is not immediately available to address t' ::)fication issues.

Section 4.6 and Chapter 7 continue the intra and interalternatives evaluation, respectively. Section 4.6 concentrates on the core criteria relative to the single issue of backlog verification tests.

4.6 Alternative 1 Against the Corc Criteria

The 11 criteria discussed in previous sections repre''nt the chosen set of considerations for intra- and interalternative comparisons. But a narrower set would be actually applicable if the equipment backlog tests are the only concern, there is no deviation from these tests, and there is no long-term need identified. The "core criteria" eliminate the advantages of flexibility, direct control, etc. Table 4-15 lists these and the Alternative 1 scoring; the total score is 36, out of a possible 63. It should be noted that against the (4 remaining) criteria not considered to be "core criteria", Alternative 1 scores very highly (33 of 36 points).

Table 4-15

Alternative 1, Phase I, Scoring Against "Core Criteria"

Criterion	Description	Score*
1	Level of NRC Involvement	9
2	"Immediacy" of the Alternative	2
3	Costs: Initial, Yearly, Long-Term	3
8	Staffing Levels Required from NRC to Implement Alternative	7
9	Historical/Chartered Function of the NRC	3
10	Dependence on the Supplier/Vendor	8
11	Conflict-of-Interest/Conflict-of-Participants-Interest	8
	Total Score	36

*1 -- most negative
5 -- neutral
9 -- most positive

The core criteria can be viewed as an (equally) weighted set; they could also serve for direct cost/benefit evaluations of the alternative. In summarizing Alternative 1, it offers clear advantages for direct and independent NRC involvement while minimizing direct NRC staff requirements; conversely, the alternative is costly and not "immediate."

4.7 Evaluation of Alternative 1, Phase II, Against the Criteria

The Phase II evaluation parallels that for Phase I in the previous section. The only two significant changes are in the "immediacy" of the alternative and in the costs.

For the former, there is significant gain in time to complete the backlog; about 6 years in Phase II, compared to about 9 years in Phase I. Nonetheless, Phase II cannot be considered as "immediate" and its score is 3. (Phase I scored "2".)

The costs to complete the backlog are remarkably similar (Tables 4-12 and 4-13). There are some differences in long-term costs commitments between the Phases, with Phase I requiring about $8M annually and Phase II requiring about $10M annually. Since the costs are about the same, the scores should also be the same at "3".

In summary Phase II scores essentially the same as Phase I, but offers some total time savings in completion of the equipment backlog.

CHAPTER 5. ALTERNATIVE 2 - CONTRACTUAL USE OF EXISTING TEST FACILITIES

A general description of Alternative 2 was given in Sections 2.1 and 2.3; those actions will be developed in this chapter. Before detailed evaluation, it should be noted that Alternative 2 is conceptually attractive. It not only recognizes that existing test facilities could be used to perform qualification verification tests but also that their specific use can be controlled to maximize their output through judicious contracting and combinatorial use.

5.1 Alternative 2 - Briefly

This alternative represents a middle position, relative to Alternatives 1 and 3. But at the same time, it is firmly based on a realistic constraint and circumstance; it addresses the issues in light of optimal results at minimum capital expenditure while maintaining control over the verification tests. For this, and all, alternatives, "verification" is a key concept. Equipment qualification is not an objective in any alternative; the qualification function will always reside with the nuclear power industry.

Originally and specifically stated, the Alternative 2 task[4] was:

> "This task will include a study of the existing testing capabilities and availability of facilities. Each facility will be characterized with respect to size and test rate limitations. The costs associated with contract preparation, monitoring and conducting tests at these facilities will be determined with respect to several sample sizes."

In evaluating this alternative, the common scenarios will be assumed: a sequential test series, the unit standard equipment backlog, and the universal test profile. In the following sections, these major subtask will be addressed: a cataloging of facilities and capabilities based on questionnaire responses, individual facility characterizations, a workable approach to contracting, the contracts management and technical organization required to implement the alternative, and the logistics and costs associated with Alternative 2.

5.2 Existing Test Facilities Capabilities

Clearly, the first requirement in evaluating the alternative was to establish the existing test capabilities. This information was not cataloged prior to this study, nor is there even a central listing of organizations who perform (any generic part of) safety-related equipment qualification. Therefore, a questionnaire was sent out requesting detailed capabilities information; this aspect is discussed in Sections 5.2.1 and Appendix C. The immediate result was a large body of interesting, but "raw" data (Section 5.2.2 and Appendix C); we have chosen to code this information to prevent user-industry "shopping" based on the work or to give an implied recommendation or competitive advantage to any test organization. The raw data, to be useful in this study, was reduced into a standard format (Section 5.2.3 and Appendix C) for further evaluation.

5.2.1 The Survey and Responses

In designing the questionnaire, it was intended to invoke some response on the part of the participants. The questions fell into two broad categories: general (yes/no) information relating to organization, historical involvement, and interest in being associated with testing for the NRC; specific, detailed, information on test capabilities for particular types of test.

Development of the questionnaire and format proceeded by (1) surveying existing regulations to determine types of tests required, (2) assessing what information was essential in the Alternative 2 evaluation process, and (3) refining the developing questionnaire by circulating it to Sandia and IE personnel, with experience in qualification testing, for review and comment. This latter step produced an expansion, reordering, and detailing of significant questions and types of tests of potential interest. The resulting questionnaire is included in Appendix C.

Careful examination of the questionnaire would reveal that the questions go somewhat beyond the immediate requirements necessary for Alternative 2. Questions on seismic test capabilities and numerous simultaneous testing combinations were included to take full advantage of the opportunity afforded by the study. This information is available for later use and reference as required; they will not be specifically used in the Alternative 2 evaluation.

A cover letter was attached to the questionnaire which described the purpose for the study, the importance of comprehensive responses to the questions to the extent practicable, the ultimate use and disposition of the results, and the method for assuring anonymity of the respondents. (The cover letter is also included in the appendix.) The original mailing list was also attached to the questionnaire to allow responding organizations to suggest other companies engaged in qualification testing.

The mailing list was compiled from Sandia and NRC staff input and from trade journals' services listings. A first mailing to 107 organizations was made in September, 1978; subsequently, 14 additional mailings were made. In an effort to provide additional stimulation, a reminder memorandum was sent to the nonrespondents in November. The completed mailings were made to 121 organizations, grouped as follows: 21 goverment or government-contract agencies, 5 academic institutions, and 95 commercial companies.

Table 5-1 summarizes the responses of the 65 organizations who ultimately returned the questionnaire.

Table 5-1

Actual General Responses, Number of Companies

1. Is your organization a:

1.	Testing division of a manufacturing company	12
2.	Testing laboratory	13
3.	Government laboratory	11
4.	Nonprofit organization	9
5.	Total respondents	65

2. Do you perform qualification testing for the nuclear industry?

   Yes G4, A4, C19 No G5, A1, C16

3. Would you perform qualification testing for the Nuclear Regulatory Commission?

   Yes G6, A5, C22 No G0, A0, C7

4. Would you perform independent qualification testing for the Nuclear Regulatory Commission on equipment similar to that already tested for companies in the private sector?

   Yes G5, A4, C21 No G1, A0, C7

Note: G = Government

A = Nonprofit or academic

C = Commercial

5.2.2 "Raw" Data

The responses ranged from outright-refusal-to-participate, to nil-information, to bound reports. The raw data represents a substantial accumulation of information in and of itself; it is analyzed in Appendix C. A yes/no matrix of type-of-test capability is compared against each company; this listing is further divided to distinguish between government, academic, or commercial affiliations. The specific organization is coded with a three-digit number. Statistically, the responses are interesting. Thirteen of 21 government agencies responded; 6 respondents have no (admitted) capability to perform any of the tests; 1 respondent is known to have test capability as evidenced by open literature publications but declined to participate by stating:

> "Because of our role as a research and development laboratory it is inappropriate for us to participate in qualification testing on a routine basis. Since we do not have qualification testing facilities suitable to provide routine testing as a service, we cannot meaningfully contribute to your questionnaire survey. We would be happy to propose development activities where improvements in the state-of-the-art of qualification testing are needed."

In summary, six government organizations (001, 006, 074, 097, 119, 124) have, at least, some test capability that could be available to support NRC-sponsored qualification verification tests. Among the eight no-response companies, most could do some radiation testing of very small test components, but have not done any extensive qualification testing (as far as is known to the author). It is believed that the six government respondents represent the bulk of the government agency qualification verification testing capability.

The academic organizations responded completely, five of five. Of these, three have only radiation services available; the other two (079, 089) claim to offer, more or less, complete environmental testing services.

Commercial organizations represent the majority of the respondents. Experience and the open literature suggest that the bulk of the directly applicable environmental testing capability resides in the commercial sector. That experience exists within two segments of the industry: (1) manufacturers having test facilities primarily for their own products and (2) independent testing laboratories (sometimes nonprofit) that provide such services. Facilities of the former organizations tend to be specific to the product line being tested (e.g., specific size, monitoring, loading, diagnostics, etc). Facilities of the test laboratories tend to be more general to accommodate the diversity of products.

Of the 45 commercial respondents, 24 manufacture a product. Although some have in-house testing capabilities, only three (007, 014, 101) have sufficient capability to aid in a qualification verification testing program. One of these, 007, apparently has rather complete testing facilities including a spent-fuel irradiation source.

The remaining, nonprofit and testing laboratory, organizations (003, 017, 023, 026, 051, 057, 059, 065, 067, 077, 092) clearly have the majority of the capability and experience. Eleven of these offer routine qualification testing to the industry, but of the eleven, one offers radiation service only, seven offer all but radiation services, one offers complete services, the other two offer various kinds of related services.

Before proceeding further and for completeness, the known capabilities among the commercial nonrespondents should be discussed. Among those, 16 have some applicable capability that is widely recognized. Six would be classified as test laboratories (012, 049, 086, 102, 105, 111); at least three of these have radiation sources. The 10 manufacturers (027, 030, 047, 054, 068, 075, 081, 084, 088, 100) are principle suppliers of safety-related equipment and have conducted and reported various qualification tests in the past. These 16 represent known additional capability.

5.2.3 Capability by Company and Category

A second compilation of the data is also shown in Appendix C, compiled by capability of each company and by company affiliation. Based on the analysis of the raw data (see the previous section discussion), only the principals having the most "useful" facilities are so compiled; this includes 11 testing laboratories, 3 manufacturers, 5 academic institutions, and 6 government-affiliated laboratories. This listing can be considered to be the majority of the U.S. qualification and qualification verification testing capability; but even within this larger grouping, a core group of primary laboratories can be identified, which are the major commercial test laboratories.

5.3 Review of the Ground Rules

The assumptions applicable in Alternative 1 (Chapter 3 and Section 4.2) are generally used as bases in this alternative as well.

The equipment backlog is the UEC-generated list of 28 generic safety-related items and their subset-types outlined in Appendix A.

The universal test profile used in the Alternative 1 study by FIRL is also appropriate here. Further, the entire test sequence adopted in the FIRL work will serve as the basis here as well; that test sequence, as summarized in Table 3-3, includes: base line functional tests, accelerated thermal aging, radiation, vibration, operational cycling, steam and chemical spray (LOCA), and post-LOCA test and inspection.

Unlike Alternative 1, Alternative 2 does not have a corollary to the consideration of sizing a facility to meet an end goal (e.g., all backlog verification testing to be completed in 18 months). While it is possible to characterize each of the 25 major test facilities (identified in the previous subsection) "...with respect to size and test rate limitations," as suggested in the original task statement, it is not particularly useful to do so. Rather for purposes of the Alternative 2 evaluation, we will propose a scheme making maximum and efficient use of the available test facilities in concert, not separately. Separate evaluation makes little sense, in fact, when most facilities do not offer radiation services (or some other particular, required, service). Only a few facilities (i.e., 007, 026, and possibly 079 and 089) suggest that they offer "complete" services; even these would require more detailed evaluation, on-site inspection, and request-for-quotes to establish that "completeness." But taken as an ensemble, the existing test facilities clearly offer complete services when co-mingled. Sufficient proof is that qualification tests are routinely being conducted within the industry today; QED, they can be done.

An added cost associated with this alternative, as with Alternative 1, is the necessity to purchase safety-related equipment for the verification tests. This cost is outlined in Section 4.4.2, and its associated tables. Briefly, the cost of in-containment equipment (one of each type) totals about $700K, but some 70% of that total is due to four control and four instrumentation penetrations at $60K each. The ex-containment equipment totals about $420K, with 60% of that required for the purchase of five radiation monitoring systems at $50K each. The total cost of all equipment is $1,116K; but if these three generic items are excluded, the total is a more modest $386K.

5.4 The Organizational Structure to Implement Alternative 2

Alternative 2 will be scoped on the basis of effective use of the major available contract testing facilities, when used in concert. It is assumed that the work backlog is sufficiently distributed so that no single facility is forced to add (significantly) to its permanent staff. Further, it is assumed that no (significant) capital equipment expenditures will be made by, or for, any facility. These points are implicit in the concept of "contractual use of existing test facilities."

This alternative closely parallels Alternative 1 in its detailing. Like Alternative 1 there is a preoperational implementation phase in which the organizational structure is established, contracts are negotiated, and equipment for test are obtained. During the operational phase, backlog equipment tests are conducted, analyzed, and reported. Following the backlog tests, the organizational structure must be reshaped to its pseudo-permanent functions (and these must be defined).

5.4.1 The Formative Stage

Clearly, the capability is not instantly available to perform qualification verification tests. From formal commitments to proceed with the program, the sequence requires: acquisition of contracts, engineering, and support staff; detailed scheduling/prioritizing of equipment backlog tests and logistics workup; request-for-quote bidding specification preparation; preparation/completion of qualified bidders list; test equipment procurement; and subcontractor bidding, negotiation, and placement.

Table 5-2 outlines the major efforts, milestones, and timing leading to the initiation of the verification tests. The timing is neither a minimum nor a maximum, but intended to be somewhat realistic. While the tasks and timing are individually arguable surely the total time is accurate within a span of 6 to 9 months, or better. The 2 years 11 months to achieve first-test-initiation status is a formidable obstacle to the alternative as a "timely" workable solution. Key assumptions in this table deserve some additional amplification.

The project will require full-time and direct NRC support, at least at a full branch-equivalent level. Four FTE (full-time equivalent) staff are recommended here; total miscellaneous staffing would be greater to accomplish necessary reviews and decision making. (This latter category could exceed 10 FTE, and is considered indirect cost in this writeup.) The first 8-months' activity would concentrate on the master contractor selection. The subsequent years, before routine testing, would be spent in financial programming, NRC/operator liaison, and planning reviews/decisions. During full operation, the NRC staff work would expand to accomplish the role of direct NRC involvement in the verification tests.

The level-of-effort and, more specifically, the nature-of-the-effort virtually demands the services of a master contractor. It is highly unlikely that efficient subcontracting/purchasing could be handled within the typical governmental framework; sole-sourcing and prequalification of bidders, for example, become laborious and time consuming within that framework. It is also recommended that the contractor have existing experience and facilities. With existing facilities, necessary support services (e.g., secretarial, office space, purchasing) can be immediately obtained at the (fluctuating) levels that may be required. Additional delays are implied if an unexperienced contractor is chosen.

Staffing by the "operator" should follow a consistent pattern. Experienced (qualification) engineers and some contracts personnel would make up the early staff; the project director would be included in this group and would be expected to continue at least through the equipment backlog verification tests to assure continuity and outlook. In later years, more of the support personnel would be selected. The ultimate personnel matrix would be staffed primarily with contract administrators and engineers with support from purchasing and logistics staff to assure timely delivery/transfer of the test equipment. The engineering sections have the final responsibility for data, testing, results, technical quality, etc. The contracts section assures the subcontractors performances.

The information collected in the survey was not intended to be sufficiently detailed to allow immediate contract placement or even provide exact detailed capabilities. In some cases, the respondents expressed unwillingness, or reluctance, to participate in NRC verification tests (or, at least, to retest products of their own manufacture or for which they performed the original qualification tests). To make the final evaluation of capability and corporate willingness, it is appropriate to develop a qualified bidders list. It is also the goal of this prebid survey, to judge the necessity for, and amount of, standardization of test method and procedures necessary to allow interlaboratory comparison of results. This concept is discussed further below.

It is to be expected that conceptually equivalent qualification tests are not necessarily procedurally equivalent on an interlaboratory basis. It is important in these verification tests to remove any laboratory influences or biases, real or imagined. To this end, a companion bid specification should be developed to outline test procedure, method, conduct, data analyses, record keeping, reporting, etc. This "standardized" laboratory specification would be a separately bid package which would accompany the request-for-quote (RFQ) to accomplish the equipment backlog verification testing. The returned quotation on the former specification would detail all costs and schedules to assure conformance as a "standardized" laboratory; it is expected that most conformance would be procedural, but a very limited amount of capital-like expenditures may also be necessary. Before the tests begin, the laboratory(s) chosen would be separately funded to, and be brought to, conform.

Table 5-2

Alternative 2 - The Formative Stages

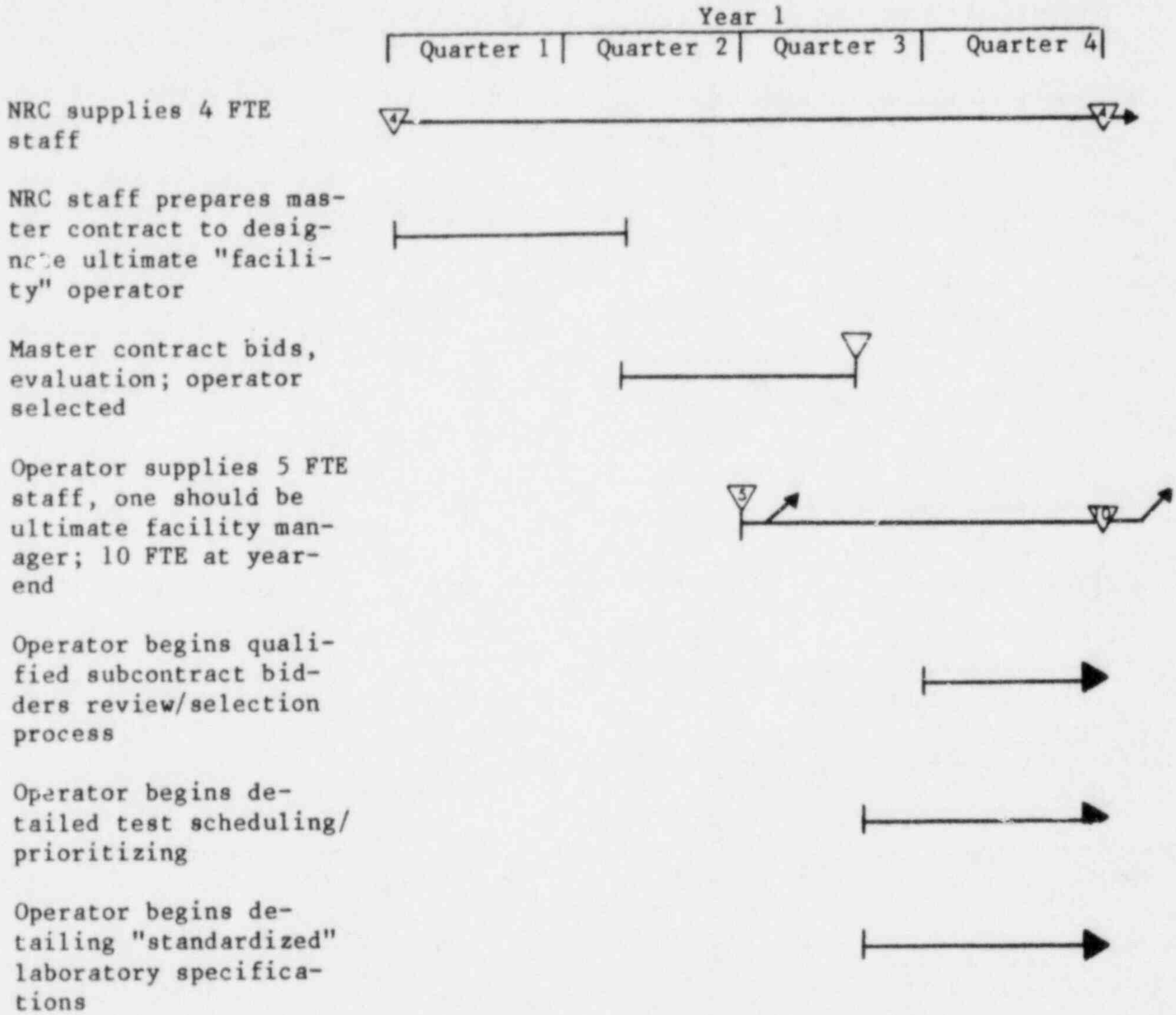


Table 5-2 (cont)

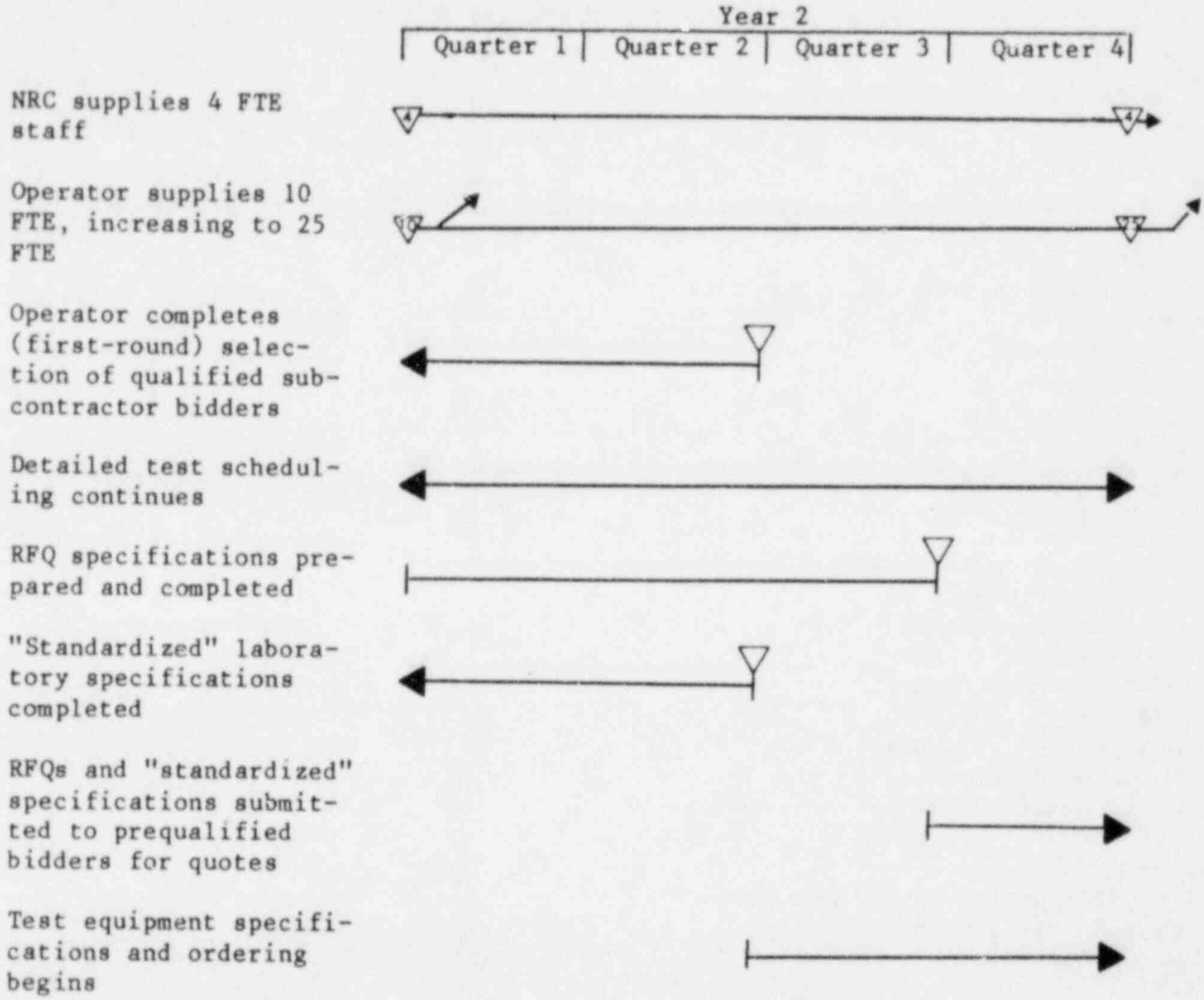
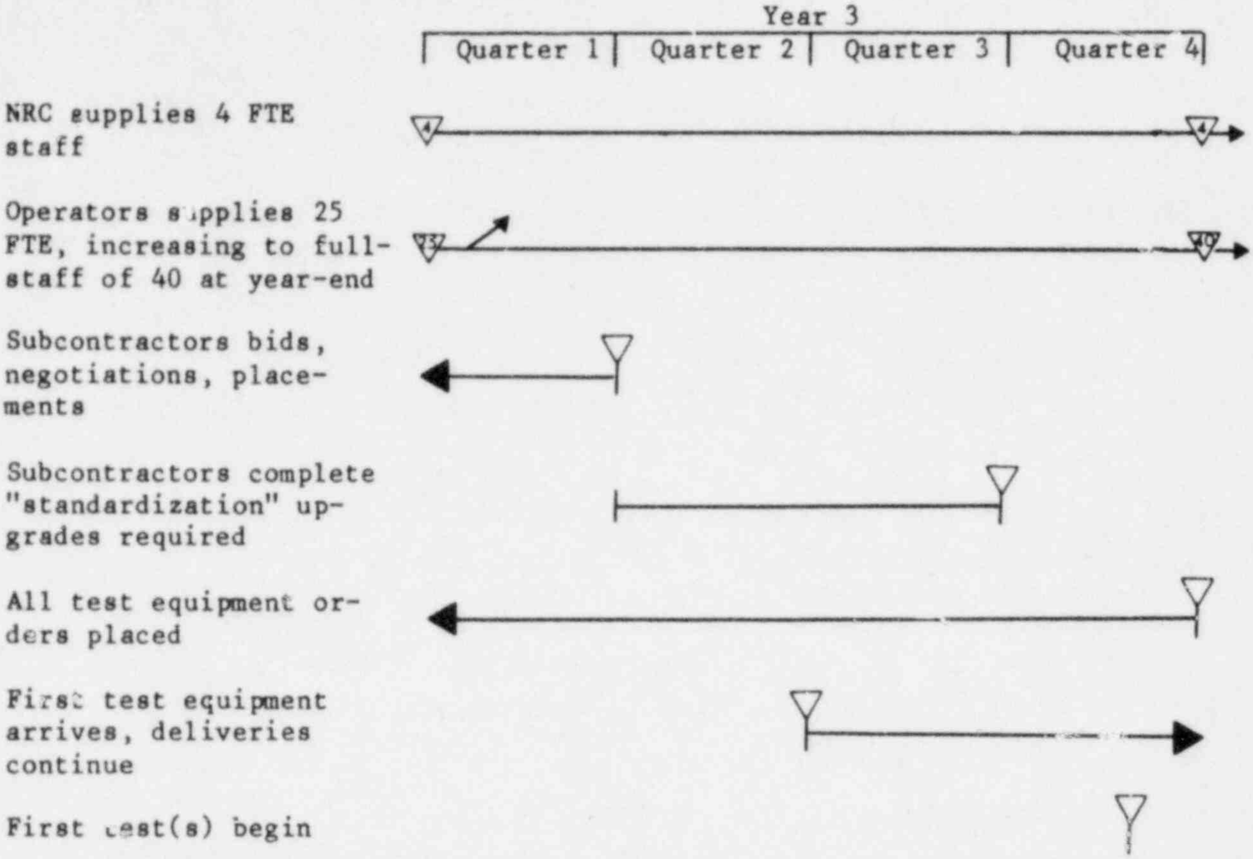


Table 5-2 (cont)



To summarize this section, Table 5-3 provides a year-by-year breakdown of the major milestones and costs to achieve routine test capability. The costs do not include subcontractor or test equipment cost.

5.4.2 Major Contractor Staff Development and Character

It has been assumed that the major contractor chosen has the background of being an existing facility from which essential services can be obtained. The costs for these are not specifically detailed, but a surcharge is assumed in the presentation below. The ultimate staff reaches 40 people at the end of the third year; staff development and character is illustrated in Table 5-4.

5.4.3 Contractor/Subcontractor(s) Interface and Structure

Previous sections of this chapter have alluded to how the existing testing facilities can be used to maximum advantage. Certainly it is not necessarily efficient to use a facility because it exists. It is, therefore, reasonable to assume that two to four "major" laboratories will serve as core facilities, supported (perhaps for radiation services, for example) by two or three "minor" laboratories. The major contractor would then be free to subcontract with these so as to optimize facility loading, logistics, and subcontractor staffing workloads.

It is not appropriate here to detail the exact subcontracting format; the first year(s) of the project existence is intended to be spent in detailing that effort. However a suggested format can be addressed as a model basis to estimate yearly costs, times to complete the backlog, impact on the (subcontracted) laboratories, and other implications of Alternative 2.

Table 5-3

Alternative 2 - Milestone and Costs - The Formative Stages

During Year	Major Milestones	Direct* NRC Cost (K$)	Indirect NRC Cost (to 10 FTE at year 3 and beyond) (K$)	Master-Contractor** Costs (K$)
1	Master contractor selected	200	50 (1 FTE)	222
2	Qualified bidders selected; RFQs for quotes	220	275 (5 FTE)	918
3	Subcontractors selected; subcontractors are "standardized"; all test equipment orders placed; first test equipment arrives first test(s) begins	250	625 (10 FTE)	1542
		670	950	2682

*Figured at 4 FTE at $50K annual loaded salary, plus 10% increase per year.

**Discussed in Section 5.4.2.

Table 5-4

Alternative 2 - Staffing Levels

	Title/Function	Annual Salary (K$)	Number of Employees at Salary	Total Yearly Salaries (K$)	With 100% Overhead (K$)	Plus 20% Services Charge (K$)
To Start	Director	32.5	1	32.5		
	Engineers	23.5	2	47		
	Contracts Adminstrators	16	1	16		
	Secretary	8.4	1	8.4		
	To Start Totals		5	103.9	207.8	249.36
End Year 1	Director	35	1	35		
	Engineers	25.5	2	51		
	Engineers	23.5	3	70.5		
	Contracts Adminstrators	17	3	51		
	Secretary	8.8	1	8.8		
	End Year 1 Totals		10	216.3	532.6	639.12
End Year 2	Director	42.2	1	42.2		
	Secretary/Receptionist	9.2	1	9.2		
	Engineering Section					
	Manager	27.5	1	27.5		
	Engineers	25.5	5	127.5		
	Engineers	23.5	3	70.5		
	QA/Inspectors	19.3	2	38.6		
	Secretary	8.4	1 1/2	12.6		
	Contracts Section					
	Manager	23.1	1	23.1		
	Contract Administrator	18.5	2	37		
	Contract Administrator	17	3	51		
	Secretary	8.4	1	8.4		
	Purchasing/Logistics Section					
	Manager	17.5	1	17.5		
	Order Analysts	14.9	2	29.8		
	Secretary	8.4	1/2	4.2		
	End Year 2 Totals		25	499.1	998.2	1197.84

Table 5-4 (cont)

	Title/Function	Annual Salary (K$)	Number of Employees at Salary	Total Yearly Salaries (K$)	With 100% Overhead (K$)	Plus 20% Services Charge (K$)
End Year 3	Director	47.5	1	47.5		
	Secretary/Receptionist	9.6	1	9.6		
	Engineering Section One					
	Manager	28.5	1	28.5		
	Engineers	26.5	1	26.5		
	Engineers	25.5	2	51		
	Engineers	23.5	3	70.5		
	QA/Inspectors	23.5	1	23.5		
	QA/Inspectors	19.3	2	38.6		
	Technicians	12.2	3	36.6		
	Secretary	8	1 1/2	12.9		
	Engineering Section Two					
	Manager	28.5	1	28.5		
	Engineers	26.5	2	53		
	Engineers	25.5	3	76.5		
	QA/Inspector	23.5	1	23.5		
	QA/Inspector	19.3	1	19.3		
	Technicains	12.2	2	24.4		
	Secretary	8.4	1	8.4		
	Contracts Section					
	Manager	25.2	1	25.2		
	Contracts Administrator	19	2	38		
	Contracts Administrator	17.5	3	52.5		
	Secretary	8.4	1	8.4		
	Purchasing/Logistics Section					
	Manager	19	1	19		
	Order Analysts	15.2	3	45.6		
	Traffic Manager	14.6	1	14.6		
	Secretary	8.4	1/2	4.2		
	End Year 3 Totals		40	786.3	1572.6	1887.12

One subcontracting technique is to guarantee yearly support at a specific level-of-effort; in effect that technique would support a certain staff, certain facilities, etc, whether or not they are actually used. Generally, less than the expected maximum level-of-effort is supported. By guaranteeing, say, a 50% level of expected use, the subcontract could bind the subcontractor to supply up to the 100% level upon demand. Overall such an arrangement effectively binds the subcontractors, but also allows the major contractor to shift the workloads and schedules to meet unforseen occurrences. This "shifting" probably can be accommodated within a factor of 2 (50% to 100%) without economic penalty.

5.4.4 The Testing Period

The subcontracts will be primarily for test services. Data analyses and reporting will be the function of the master contractor. During the backlog testing period, the level of test effort, manpower required, and overall costs should closely parallel those associated with the same-phase period of the dedicated test facility, Alternative 1. The reasoning is straightforward; the equipment backlog, i.e., the number of tests required, are identical in the two alternatives. Although some argument can be made for efficiency of multi-identical tests within a given laboratory, the tests/personnel, or cost/test, ratios are not much affected; an offsetting penalty is that of contracting tests at geographically diverse facilities and the logistics of that arrangement.

The time to complete the equipment backlog verification tests, once begun, is comparable to the prologue period. Recall that the Alternative 1, Phase I, study resulted in an estimated 4-year period if 2 LOCA-simulation chambers were used; the Phase II study resulted in an estimated 18-month period when 8 chambers were used. These time/chamber ratios should be appropriate for Alternative 2 as well.

At one extreme then, the minimum testing time is solely based on the number of LOCA-simulation chambers. From the Appendix C data, that number is very large. More realistically, it is likely that perhaps two chambers from each of four major contractors could be used efficiently.

Coupled with the logistics problems, it would require an estimated 18 to 24 months to complete the testing. Another limiting factor is the master contractor staff; their capability to respond and produce test evaluations and reports in any shorter period is doubtful. The point is that a "timely" response is not a strong function of the test backlog but of the time to get to the point of routine testing and then the test reporting.

The costs of this phase can be approximated by arguing that the total cost is almost invariant from that estimated for staffing and overhead costs of Phase II of Alternative 1, because the workload is virtually identical. Part of the cost is retained by the master contractor. For example during year 4, the first year of tests, that is about $1900K. The balance would be performed under contract. Table 13-7 of the FRC report (Appendix B) estimates a total cost of about $13,0[illegible] to complete the 18-month equipment backlog. Table 5-5 summarizes the Alternative 2 funding schedule retaining that total value; that is, the subcontract costs and the major contractor staff costs (during the 18-month test period) total $13,000K. Similarly the equipment costs total the $1,116K.

5.4.5 "Post-Backlog" Uses, Maintain the Capability

Once the equipment verification tests backlog is completed, 40 staff of the master contractor remain, at a $2.3M+ annual salary. While it is conceivable that they could be absorbed into the (larger) parent company, it is more reasonable that adjustment costs will be demanded in the master contract. Conversely, an a'priori recognized long-term future must be identified to increase the viability of this alternative.

Two immediate needs could be considered. First, a continuing stream of new or modified equipment will require qualification verification tests. And/or new test profiles may emerge which could require testing of previously tested equipment.

Table 5-5

	Year 1	Year 2	Year 3	Year 4	(Six Months) Year 4-4 1/2	Annual Followon
NRC staff	200	220	250	275	150	325
Master Contractor Staff	222	918	1542	1900	1000	2300
Subcontractors	--	--	500	6000	4100	1000
Equipment Costs	--	--	200	800	116	200
Yearly	422	1138	2492	8975	5366	3825
Cumulative	422	1560	4052	13,027	18,393	
				←~18 month testing→		
Additional Indirect NRC Staff (to 10 FTE at year 3 and beyond)	50	275	625	700	400	875

Secondly, with some alteration/supplementation of staff, the efforts of the organization could be directed toward evaluation of qualification testing methodologies and general research applications. Each test sequence has potential for research: thermal aging, radiation application, vibration, operational cycling, and LOCA simulation. In addition, research into extensions of the state-of-the-art may also be appropriate.

But while the former long-term need is real and compatible with "contractual use of existing test facilities," the ability to conduct "efficient" research is not so certain without on-site, captive, test facilities. It should be possible to establish long-term subcontracts to accomplish this research, but the overall efficiency of doing so would need to be closely scrutinized.

It is not within the scope of this report to thoroughly examine these areas. But since the annual operating costs are solely for staff, the level of long-term-use and the yearly cost are adjustable to meet whatever needs are identified.

5.4.6 Other Implications of the Alternative

The implications of the alternative extend beyond costs and time discussed above and are both positive and negative.

Since commercial industry facilities will be subcontracted, there is opportunity to arrive at differing results for the same equipment at the same test laboratories. This could be awkward for the laboratories and thought should be given to this eventuality. It may preclude participation, by some (essential) segments of the industry, in order to protect and assure long-standing industry-laboratory relationships. This is particularly true if the test laboratory only perceives the verification tests as a one-time, nonrepetitive, source of income; the laboratories may contractually demand longer-term commitments.

During the verification tests, these facilities are not also available for other commercial users. Thus, the effect of NRC-sponsored tests may be to delay and upset the normal industry routine. Depending upon the exact test timing, this represents a greater or lesser direct impact on the nuclear industry in general.

If the subcontracted test laboratories are "standardized" for purposes of these verification tests, it is assumed that the capability will be maintained (at some level) and be available to general industry testing. The effect could be to upgrade, or at least standardize, qualification testing. Consequently, test results should be more acceptable to NRC during the regulatory process. Conversely, the effect is, to some extent, preferential, if not <u>all</u> test facilities are upgraded, even those not directly subcontracted for verification tests. In fact, direct subcontracting to a commercial laboratory, even without upgrading or standardizing, has an implied NRC acceptability of the facility and an associated intangible competitive advantage in the marketplace. The legal ramifications of "contractual use of existing test facilities" is an area which may require additional consideration.

5.5 Evaluation of Alternative 2 Against the Criteria

Before detailed discussion of each criterion, Table 5-6 summarizes the scoring of the alternative; justification of the selected scoring is given in the criterion evaluation writeups below. Section 5.6 co inues the criteria evaluation but with regard to a quasi cost/benefit format and with some discussion of relative criterion importances. Criterion with an asterisk (*) indicates a "core" criterion as described in Section 3.4.2.

Table 5-6

Alternative 2 Scoring

Criterion	Description	Score*
1	Level of NRC Involvement	8
2	"Immediacy" of the Alternative	3
3	Costs: Initial, Yearly, Long-Term	4
4	Direct Control of Prior-Tests Verifications	6
5	Flexibility	6
6	Degree of Control Available	4
7	Long-Term Use Potential	6
8	Staffing Levels Required from NRC to Implement Alternative	7
9	Historical/Chartered Function of the NRC	3
10	Dependence on the Supplier/Vendor	4
11	Conflict-of-Interest/Conflict-of-Participants-Interest	3
	Total Score	54

*1 -- most negative
5 -- neutral
9 -- most positive

5.5.1 Individual Criterion Discussion

(*) Criterion 1: Level of NRC Involvement: By judicious subcontracting, the desired level of NRC involvement can be obtained. In this alternative however, the NRC is twice removed from the actual testing (major project contractor, subcontractor(s)). The logistics of separated test facilities also makes the constant presence of NRC staff somewhat difficult. All in all, Alternative 2 does offer a high level of NRC involvement and is therefore very attractive; this is reflected in the score of 8.

(*) Criterion 2: "Immediacy" of the Alternative: Alternative 2 is somewhat time-consuming to implement. Relative to the rather short backlog test duration expected (18 months), the 2-year 11-month period to implement the alternative is particularly striking. Interestingly, this implementation time is strictly procedural, since essentially no capital expenditures are necessary. It is not apparent that the implementation time is subject to significant reduction by over-stress techniques. The alternative is negative overall with respect to this criterion, and is so reflected in the score of 3.

(*) Criterion 3: Cost, Initial, Yearly, Long-term: With regard to costs, this alternative suffers in three respects. First, the direct costs to conduct the tests are high, plus the purchase of test equipment. Second, there are ever-increasing yearly costs during the 2-year 11-month implementation period which are not immediately offset with results. Third, the dedicated contract staff has to be used in the long-term, and/or adjusted, and/or terminated at various cost commitment levels. On the other hand, none of these costs are prohibitive and, in fact, are relatively reasonable when compared with other major NRC-budget programs. The score is 4.

Criterion 4: Direct Control of Prior-Tests Verifications: The adaptability of this alternative to respond to questions concerning in-place equipment qualification is real. Though such testing could be negotiated by subcontract, nuclear-industry reluctance is probable. Similarly there could be difficulties in obtaining equipment for test. It is conceivable that a direct NRC order would be necessary, for example, to obtain spare equipment items. For those older equipment items no longer directly available from the manufacturer, other, directly technical, problems in obtaining it are evident.

The alternative does not preclude this function, yet since additional and separate subcontracting and negotiation is required, it is not strongly positive with respect to the criterion; the score is 6.

Criterion 5: Flexibility: Subcontracts can be written judiciously with flexibility and subcontracts can be renegotiated if required, but "flexibility" is not normally associated with subcontracting. The score is 6.

Criterion 6: Degree of Control Available: Control is a direct result of the legal subcontract. In general, unless penalty clauses are written and/or can be enforced, the contractor can only terminate the contract for noncompliance and the subcontractor need only perform to the contract. Again the "degree of control" is a function of the judiciousness with which the contract is written. The alternative is judged to be negative with respect to the criterion and the score is 4.

Criterion 7: Long-Term Use Potential: Since the alternative does not involve direct capital expenditures with tangible value, it has no long-term use potential in that narrowest aspect. On the other hand, a specific staff is available to adjust to long-term needs, a positive factor. It is judged that the alternative is slightly positive with respect to the criterion with a score of 6.

(*) Criterion 8: Staffing Levels Required from NRC to Implement Alternative: Direct NRC manpower necessary to initiate and guide this alternative are low, estimated to be four FTE personnel. Here, direct manpower is to be distinguished from contractor and subcontractor costs as described in Criterion 3. Neither does the four FTE estimate consider other NRC reviewer/management overhead, generally an intangible item and included in the routine NRC function (estimated at 10 FTE in Tables 5-3 and 5-5). In general, the lower the direct NRC manpower requirements, the greater the (positive) score for this criterion. The score of 7 reflects the strongly positive features of this criterion, while recognizing that some dedicated NRC manpower will need to be diverted to this program to assure its success.

(*) Criterion 9: Historical/Chartered Function of the NRC: Direct involvement in qualification verification tests would be a new experience to the NRC. It is virtually imperative that actual testing be conducted by a captive contractor/subcontractor organization to avoid the restrictive features of civil service subcontracting, purchasing, sole-source contracts, etc.

To select Alternative 2 is to realize that all tests and results are directly available to the general public and are subject to scrutiny and interpretation. This will pressure all participants to an even greater degree than that which currently exists. There will be little opportunity to use engineering judgment in the test results or to account for "grey" areas in a normal scientific fashion; i.e., any test result will be viewed as only pass/fail by some interested parties.

Although these tests are not intended to be qualification tests (as distinguished from verification and/or research tests) new licensees may attempt to umbrella their equipment and claim qualification through them. Alternative 2 would then require careful ongoing attention to clearly distinguish its goals and objectives and industry relationships.

Since the factors are essentially negative and since Alternative 2 represents a new course for NRC, the score is 3.

(*) Criterion 10: Dependence on the Supplier/Vendor: The actual conduct of the verification tests depends upon the timely supply of equipment for testing. This implies two separate uncertainties. First, vendor supply of a one-of-a-kind item is normally subject to large delivery schedule slippages and uncertainties. Second, the satisfactory certification that the vendor has supplied the actual "type" to be used in the field is a concern. By way of contrast, this latter concern is lessened where, and if, a test item can be selected directly from a larger order of such equipment; but this implies substantial effort to conduct tests in concert with equipment deliveries to ultimate users and as a result to be somewhat "at the mercy" of these users and vendors.

It is clear that any alternative selected cannot entirely avoid these problems. More than likely, it will be necessary (on occasion) to use implicit, or explicit, legal "clout" to accomplish overall aims and schedules. Alternative 2 does offer some overall flexibility to accommodate the criterion; the score is 4, slightly negative.

(*) Criterion 11: Conflict-of-Interest/Conflict-of-Participants-Interests: By subcontracting to third parties, it becomes increasingly more difficult to maintain "at-arms-length" transactions. It is particularly true in the case of Alternative 2, where subcontracts would be placed with the same commercial laboratories that perform tests for the nuclear industry which are, in turn, regulated by the NRC. This "daisy chain" effect gives the illusion (even when untrue) of "conflict-of-interest."

Similarly, the commercial laboratories recognized some difficulties and expressed some reluctance in their survey/questionnaire responses with respect to their client relationships. It remains to be seen whether the commercial laboratories can even be persuaded to bid to the subcontracts.

Alternative 2 offers particular concerns with respect to this criterion; the score is 3.

5.5.2 Alte native 2 "Scoring" Summary

Alternative 2 is somewhat neutral in its scoring to these criteria; the alternative scores highly only with respect to the level of NRC involvement, and is highly negative with respect to three (Criterion 2, 9, 11,). The total unweighted score is 54, out of a possible 99.

Section 5.6 and Chapter 7 continue the intra- and interalternatives evaluation, respectively. Section 5.6 concentrates on the core criteria relative to the single issue of backlog verification tests.

5.6 Alternative 2 Against the Core Criteria

The 11 criteria discussed in previous sections represent the chosen set of considerations for intra- and interalternative comparisons. But a narrower set would be actually applicable if the equipment backlog tests are the only concern, there is no deviation from these tests, and there is no long-term need identified. The "core criteria" eliminate the advantages of flexibility, direct control, etc. Table 5-7 lists these and the Alternative 2 scoring; the total score is 32, out of a possible 63. It should be noted that against the (4 remaining) criteria not considered to be "core criteria," Alternative 2 scores only moderately (22 of 36 points).

Table 5-7

Alternative 2 Scoring Against "Core Criteria"

Criterion	Description	Score*
1	Level of NRC Involvement	8
2	"Immediacy" of the Alternative	3
3	Costs: Initial, Yearly, Long-Term	4
8	Staffing Levels Required from NRC to Implement Alternative	7
9	Historical/Chartered Function of the NRC	3
10	Dependence on the Supplier/Vendor	4
11	Conflict-of-Interest/Conflict-of-Participants-Interest	3
	Total Score	32

*1 -- most negative
5 -- neutral
9 -- most positive

The core criteria can be viewed as an (equally) weighted set; they could also serve for direct cost/benefit evaluations of the alternative. In summarizing Alternative 2, it offers clear advantages for direct and independent NRC involvement while minimizing direct NRC staff requirements; conversely, the alternative is not "immediate" and has potentially severe conflict-of-participants interests (and conflict-of-interest) problems.

CHAPTER 6. ALTERNATIVE 3 - SURVEILLANCE OF VENDOR TESTS

A general description of Alternative 3 was given in Sections 2.1 and 2.4 previously; those sections will be developed further in this chapter. This alternative represents a minimal extrapolation from the historical NRC involvement in the evaluation of safety-related equipment qualification testing (i.e., test review and witnessing). From that standpoint, it is an attractive concept. On the other hand, it can be recognized a'priori that the alternative sacrifices direct control over testing, scheduling, equipment selection, and the like, except for the explicit and implicit coercive powers of the regulatory authority.

6.1 Alternative 3 - Briefly

This alternative is minimal in concept with comparison to Alternatives 1 and 2. Depending upon its level of implementation, it can be an absolutely minimal, or an extensive, response with respect to an increased, direct, NRC involvement in safety-related equipment qualification verification testing. That is to say, its gradations could range from one dedicated staff member, to many; each additional staff represents "increased and direct NRC involvement." For this, and all alternatives, it must be reiterated that "verification" is a key concept. Equipment qualification is not an objective in any alternative; the qualification function will always reside with the nuclear power industry.

Originally and specifically stated, the Alternative 3 Task[4] was:

> "A study of the manpower and expense associated with this alternative will be estimated using several sample sizes. A subject of this alternative will address the benefits of upgrading the industry's present approach to qualification testing through a third party effort as an alternative to direct NRC tests."

There are two distinct and separate evaluations to accomplish this task. The first, stated as estimates of manpower and expenses using several sample (i.e., number of tests) sizes, will be somewhat restructured in this chapter. Rather than several sample sizes, an estimate of actual, and anticipated, tests and rates will be made. In this way, the manpower and organizational structure to implement the alternative will be more logically based and will allow interalternative comparisons to be made.

The second part of the task description alludes to the possibility that a part of the certification/qualification/verification effort could be delegated to (at least overseen by) some "independent" third party. Corollaries to such an activity may be found in the "N" stamp ASME program already within the nuclear industry or in the UL testing program in the general commercial electric industry. The known history of third party efforts and its potential relative to the study objectives will be discussed in the following sections.

6.2 Relationships to Alternatives 1 and 2

Alternative 3 is unique in that no contractor is involved ("NRC review and witnessing of vendor tests"), no capital expenditures or test facilities are required, and no delay in implementation of the alternative need occur once an NRC management decision is made to proceed. These clearly result in simplification of alternative implementation.

At the same time, these (and other) points make a one-to-one comparison with the other alternatives somewhat incompatible. What then is the common tie with Alternative 3? Clearly, it must be within the objectives and the Commissioners' Directive:[1]

> "Provide the Commission with an analysis of alternatives ... for conducting independent verification testing of environmentally qualified equipment which is required to operate in safety systems ..."

The directive implicitly describes the ultimate goal to be addressed as "completing" the conduct of verification tests. For Alternatives 1 and 2, that goal could be realistically translated to completing the equipment "backlog" by using common equipment and universal test profile scenarios;

these were controllable by virtue of the alternatives' options. For Alternative 3, these are variables and not controllable. The scenario of Alternative 3, by definition, must allow the industry to set the pace, kind, and quality of testing.

That is not to say that the alternative is completely open-ended. Merely, the scope of the testing effort must be redefined to account for the competition and independence within the industry. In the next section, the test load for this alternative will be defined by attempting to correlate the future with recent industry practice. With the test load then defined, Section 6.4 addresses the organizational structure to implement Alternative 3, and the alternative can be evaluated against the bases (Sections 6.5 and 6.6).

6.3 Ground Rules to Fit the Alternative

The assumptions of the unit-standard equipment "backlog" and the universal test profile are not appropriate to Alternative 3. New ground rules will be established in this section by which "greater NRC involvement" can occur through "NRC review and witnessing of vendor tests;" that is, one basic ground rule is common to all alternatives, greater NRC involvement in equipment environmental qualification. The scenario is clear; the industry will set the pace, kind, and quality of testing.

In establishing these ground rules, the aspects of each will be discussed separately in this section. Current NRC effort on inspection will be briefly reviewed; this will be used to provide a basis for establishing the capabilities of an inspector, his work load, and his function within a verification format. The "level" of NRC involvement certainly dictates the numbers of personnel required to effectively implement the alternative. The "level" is also somewhat dependent upon industry "usage" and "acceptability" of increased NRC involvement. Finally, the anticipated test load and scheduling are important factors to the implementation of Alternative 3, and these will be estimated.

6.3.1 Anticipated Test Loads and Schedules

A distinction of this alternative is that no separate verification testing will occur per se; rather, the industry will perform their routine qualification test program but with direct NRC involvement and NRC verification of test "acceptability." Since testing will not be enveloped within separate verification tests, this alternative has no clear completion milestone; that is, the "review" alternative must continue as long as qualification tests continue. At the same time, it must be recognized that Alternatives 1 and 2 have a similar feature. Except that the efforts there can be distinguished as near-term and long-term, whereas the Alternative 3 effort has one mode, continuing.

The number of tests is directly dependent upon the numbers of nuclear plants that have been, and will be, granted construction permits on the basis of IEEE 323-1974[6] (or subsequent standards). These are clearly defined by the NRC staff in NUREG-0413:[13]

> "The staff's reviews of the environmental qualification of safety-related electrical equipment for plants tendering CPs after July 1974 reflect the more comprehensive guidelines specified in IEEE Standard 323-1974 and the successive ancillary Standards."

Table 6-1, abstracted from Reference 23, lists all such plants which have entered the calendar of procedural steps for obtaining construction permits beyond July 1974. Table 6-2 further analyzes the data to distinguish the architect-engineers (AE), the type of plants, and the number of separate utilities involved.

How can this data be used to estimate the test load? Historical experience has shown that, while the plant owner/operator is ultimately responsible for safety-related equipment qualification, the programs and mechanics for conducting the qualification are generally redelegated to the AEs in conjunction with the NSSS supplier.

Table 6-1

"Backlog" Nuclear Plants (Reference 23)

Reactor Information					
		Proposed Power Level			
Name and Location (Owner/Operator)	Reactor Type (Designer)	MW(t)	MW(e)	Scheduled Completion Date	Architect-Engineer
Allens Creek 1 and 2	BWR (GE)	3579	1150	1984	Ebasco
(Houston Lighting & Power Co.)	BWR (GE)	3579	1150	1982	
Atlantic 1 and 2	PWR (West)	3411	1150	Indefinite	Offshore Power Systems
(Public Service Electric & Gas Co.)	PWR (West)	3411	1150	Indefinite	
Bellefonte 1 and 2	PWR (B&W)	3600	1213	1980	TVA
(Tennessee Valley Authority)	PWR (B&W)	3600	1213	1980	
Black Fox 1 and 2	PWR (GE)	3425	1150	1983	Black & Veatch
(Public Service Co. of Oklahoma)	BWR (GE)	3425	1150	1985	
Blue Hills 1 and 2	PWR (CE)	2814	918	Indefinite	Bechtel
(Gulf States Utilities)	PWR (CE)	2814	918	1981	
Braidwood 1 and 2	PWR (West)	3425	1120	1981	Sargent & Lundy
(Commonwealth Edision Co.)	PWR (West)	3425	1120	1982	
Byron 1 and 2	PWR (West)	3425	1120	1981	Sargent & Lundy
(Commonwealth Edision Co.)	PWR (West)	3425	1120	1982	
Callaway 1 and 2	PWR (West)	3411	1120	1982	Bechtel
(Union Electric Co.)	PWR (West)	3411	1120	1986	
Catawba 1 and 2	PWR (West)	3411	1153	1981	Utility/Duke
(Duke Power Co.)	PWR (West)	3411	1153	1982	
Cherokee 1, 2, and 3	PWR (CE)	3800	1280	1984	Utility/Duke
(Duke Power Co.)	PWR (CE)	3800	1280	1986	
	PWR (CE)	3800	1280	1988	
Clinton 1 and 2	BWR (GE)	2894	933	1982	Sargent & Lundy
(Illinois Power Co.)	BWR (GE)	2894	933	1987	
Comanche Peak 1 and 2	PWR (West)	3411	1150	1980	Gibbs & Hill
(Texas Utilities Generating Co.)	PWR (West)	3411	1150	1982	

Table 6-1 (cont)

Reactor Information					
Name and Location (Owner/Operator)	Reactor Type (Designer)	Proposed Power Level MW(t)	MW(e)	Scheduled Completion Date	Architect-Engineer
Davis-Besse 2 and 3	PWR (B&W)	2772	906	1984	Bechtel
(Toledo Edison Co.)	PWR (B&W)	2772	906	1986	
Douglas Point 1 and 2	BWR (GE)	3579	1178	Indefinite	Ebasco
(Potomac Electric Power Co.)	BWR (GE)	3579	1178	Indefinite	
Erie 1 and 2	PWR (B&W)	3760	1260	1986	Gilbert/Commonwealth
(Ohio Edison Co.)	PWR (B&W)	3760	1260	1988	
Fort Calhoun 2	PWR (West)	3425	1150	1983	Gibbs & Hill
(Omaha Public Power District)					
Grand Gulf 1 and 2	BWR (GE)	3833	1250	1980	Bechtel
(Mississippi Power & Light Co.)	BWR (GE)	3833	1250	1983	
Greene County Nuclear Power Plant	PWR (B&W)	3600	1191	1986	Stone & Webster
(Power Authority of State of NY)					
Greenwood 2 and 3	PWR (B&W)	3600	1200	1986	Bechtel
(Detroit Edison Co.)	PWR (B&W)	3600	1200	1988	
Harris 1, 2, 3, and 4	PWR (West)	2775	900	1983	Ebasco
(Carolina Power & Light Co.)	PWR (West)	2775	900	1985	
	PWR (West)	2775	900	1989	
	PWR (West)	2775	900	1989	
Hartsville 1, 2, 3, and 4	BWR (GE)	3579	1233	1982	TVA
(Tennessee Valley Authority)	BWR (GE)	3579	1233	1983	
	BWR (GE)	3579	1233	1982	
	BWR (GE)	3579	1233	1983	
Haven 1 and 2	PWR (West)	2775	900	1987	Stone & Webster
(Wisconsin Electric Power Co.)	PWR (West)	2775	900	1989	
Hope Creek 1 and 2	BWR (GE)	3293	1067	1983	Bechtel
(Public Service Electric & Gas Co.)	BWR (GE)	3293	1067	1985	
Jamesport 1 and 2	PWR (West)	3411	1150	1988	Stone & Webster
(Long Island Lighting Co.)	PWR (West)	3411	1150	1990	

Table 6-1 (cont)

Reactor Information					
		Proposed Power Level			
Name and Location (Owner/Operator)	Reactor Type (Designer)	MW(t)	MW(e)	Scheduled Completion Date	Architect-Engineer
Marble Hill 1 and 2	PWR (West)	3425	1130	1982	Sargent & Lundy
(Public Service Indiana)	PWR (West)	3425	1130	1983	
Millstone 3	PWR (West)	3411	1156	1986	Stone & Webster
(Northeast Nuclear Energy Co.)					
Montague 1 and 2	BWR (GE)	3425	1150	1988	Stone & Webster
(Northeast Nuclear Energy Co.)	BWR (GE)	3425	1150	1989	
New England Power 1 and 2	PWR (West)	3411	1150	1986	United Engineers & Constructors
(New England Power Co.)	PWR (West)	3411	1150	1988	
North Anna 3 and 4	PWR (B&W)	2631	907	1983	Stone & Webster
(Virginia Electric & Power Co.)	PWR (B&W)	2631	907	1984	
North Coast	PWR (West)	1780	583	Indefinite	Gibbs & Hill
(Puerto Rico Water Resources Authority)					
Palo Verde 1, 2, 3, 4, and 5	PWR (CE)	3817	1238	1981	Bechtel
(Arizona Public Service)	PWR (CE)	3817	1238	1983	
	PWR (CE)	3817	1238	1985	
	PWR (CE)	3817	1238	1987	
	PWR (CE)	3817	1238	1989	
Pebble Springs 1 and 2	PWR (B&W)	3600	1260	1985	Bechtel
(Portland General Electric Co.)	PWR (B&W)	3600	1260	1988	
Perkins 1, 2, and 3	PWR (CE)	3800	1280	1987	Utility/Duke
(Duke Power Co.)	PWR (CE)	3800	1280	1990	
	PWR (CE)	3800	1280	1992	
Perry 1 and 2	BWR (GE)	3579	1205	1981	Gilbert
(Cleveland Electric Illuminating Co.)	BWR (GE)	3579	1205	1982	
Phipps Bend 1 and 2	BWR (GE)	3600	1233	1983	TVA
(Tennessee Valley Authority)	BWR (GE)	3600	1233	1984	
Pilgrim 2	PWR (CE)	3456	1180	1985	Bechtel
(Boston Edition Co.)					

Table 6-1 (cont)

Reactor Information: Name and Location (Owner/Operator)	Reactor Type (Designer)	Proposed Power Level MW(t)	Proposed Power Level MW(e)	Scheduled Completion Date	Architect-Engineer
River Bend 1 and 2	BWR (GE)	2894	934	1983	Stone & Webster
(Gulf States Utilities Co.)	BWR (GE)	2894	934	Indefinite	
St. Lucie 2	PWR (CE)	2560	810	1982	Ebasco
(Florida Power & Light Co.)					
Seabrook 1 and 2	PWR (West)	3411	1200	1982	United Engineers & Constructors
(Public Service of New Hampshire)	PWR (West)	3411	1200	1984	
Skagit 1 and 2	BWR (GE)	3800	1277	1984	Bechtel
(Puget Sound Power & Light)	BWR (GE)	3800	1277	1986	
South Texas 1 and 2	PWR (West)	3800	1250	1980	Brown & Root
(Houston Lighting & Power Co.)	PWR (West)	3800	1250	1981	
Sterling 1	PWR (West)	3411	1150	1983	Bechtel
(Rochester Gas & Electric Corp.)					
Surry 3 and 4	PWR (B&W)	2631	859	1983	Stone & Webster
(Virginia Electric & Power Co.)	PWR (B&W)	2631	859	1984	
Tyrone 1	PWR (West)	3411	1150	1985	Bechtel
(Northern States Power Co.)					
Washington 1 and 4	PWR (B&W)	3600	1218	1982	United Engineers & Constructors
(Washington Public Power Supply System)	PWR (B&W)	3600	1218	1984	
Washington 3 and 5	PWR (CE)	3817	1242	1983	Ebasco
(Washington Public Power Supply System)	PWR (CE)	3817	1242	1985	
Waterford 3	PWR (CE)	3390	1113	1980	Ebasco
(Louisiana Power & Light Co.)					
Wolf Creek	PWR (West)	3411	1150	1982	Bechtel/Sargent & Lundy
(Kansas City Power & Light Co.)					
Yellow Creek 1 and 2	PWR (CE)	3800	1300	1984	TVA
(Tennessee Valley Authority)	PWR (CE)	3800	1300	1985	

Table 6-2

Architect-Engineers and Reactor Distribution (Reference 23)

AE	Type of Plant (Number of Utilities Represented) BWR (GE)	PWR (W)	PWR (CE)	PWR (B&W)
Ebasco	4 (2)	4 (1)	4 (3)	-
Offshore Power Systems	-	2 (1)	-	-
TVA	6 (1)	-	2 (1)	2 (1)
Black & Veatch	2 (1)	-	-	-
Bechtel	6 (3)	5 (4)	8 (3)	6 (3)
Sargent & Lundy	2 (1)	6 (2)	-	-
Duke	-	2 (1)	6 (1)	-
Gibbs & Hill	-	4 (3)	-	-
Gilbert/Commonwealth	2 (1)	-	-	2 (1)
Stone & Webster	4 (2)	5 (3)	-	5 (2)
United Engineers & Constructors	-	4 (2)	-	2 (1)
Brown & Root	-	2 (1)	-	-
	26 (11)	34 (18)	20 (8)	17 (8)

97 Plants (45 Utilities)

At a minimum then, the number of complete test programs would equal the number of AEs, i.e., 12. (In an absolute sense, the minimum would be 4 programs from the 4 NSSS vendors plus 12 programs from the AEs; but note that these are not complete programs since the AE and NSSS vendor separately supply only parts of the equipment to make a complete program.) More likely the programs are distinguishable by BWRs and PWRs in concert with the AEs; i.e., 18 programs (7 for BWRs, 11 for PWRs).

Continuing this exercise for PWRs alone, it can be assumed that sufficient differences exist between the NSSS suppliers that a separate program would be established for each NSSS type in concert with the AEs, i.e., 18 programs.

In the logical extreme, utilities' requirements also affect design; thus it could be that separate programs would be required for utility, architect-engineer, and reactor vendor in concert, i.e., 11 programs for BWRs and 34 programs for PWRs. (If no credit were taken for experience or duplication, then the absolute extreme numbers of programs is identical to the total numbers of plants, or 97.)

In summarizing these arguments, the expected number of BWR programs ranges from 7 to 11; the expected number of PWR programs ranges from 11 to 34. We will assume that a middle value is realistic, 9 BWR and 23 PWR programs. As a convenience, and since the numbers of equipment for BWRs is generally less than for PWRs, we will further assume that 25 equivalent test programs will be conducted on the equipment "backlog" set that was developed for scoping Alternatives 1 and 2.

The implication is that approximately 25 times more "verification" tests would need to be reviewed/witnessed by NRC staff to achieve the same "confidence level" as available through Alternatives 1 and 2, given the assumptions in this study. At the same time, it is conceivable that the number of test programs ultimately completed would be smaller by a factor of 2 or so through use of generic NSSS programs and the like. (Arguments were presented above that the number could be larger.) Clearly, the conclusion is that many "pseudo-duplicate" "verification" tests will be conducted between now and 1992 (the Perkins 3 Plant, Table 6-1, and not considering the "indefinites").

"Duplication" is slightly overstated in the sense that for a given test program only (about) one of each generic equipment type would be tested; (i.e., the one type selected for the specific plant use) instead of all the types of that generic item. Thus, in each of the 25 programs, the costs of the test items would be somewhat reduced. On the other hand, drawing from Alternative 1 and specifically Table 2-1 of Appendix B, test costs would not be substantially reduced because the assumption in the Appendix B study was to combine the equipment (especially of the same generic type) into a single test where practicable. Thus, the total number of tests would not be much reduced, and the total testing cost would be similar to that predicted for Alternative 1 or 2 per program.

[Recall that the costs for test specimens is academic for the Alternative 3 evaluation--it is not part of the scenario for the alternative. Yet it represents a real cost to the nuclear industry, thus clearly arguing for increased "standardization."]

To summarize the anticipated load, the basis for evaluating Alternative 3 will be the necessity to review/witness/evaluate 25 equivalent test programs, with the test program defined above, and with an estimated 20 full-test-sequences (Table 3-3) per test program.

As for scheduling, this is a direct function of the plant on-line schedule. As shown in Figure 6-1, a peak level of 15 plants/year is scheduled for 1982 and 1983. Equipment qualification program completions must anticipate those dates by an estimated 1 or 2 years at least. It can also be assumed that delays will continue to occur in bringing plants on line, with delays on the order of 2 or 3 years. As a result, the Figure 6-1 curve shapes are also reasonable estimates as to equipment qualification programs load. The peak load (and coincidentally the maximum NRC-surveillance personnel required) will occur circa-1983.

By ratioing the 89 plants over the 11 years between 1980 and 1990, 8 plants/year on the average are expected on-line in this period. Similarly, 25 programs in 11 years result in 2+ programs/year. By observing the factor of 2-to-1 peak-to-average ratio, the peak work load, in circa-1983, should be approximately 4 complete test programs in the single year. Similarly, by 1980, the NRC staff must be already assembled and qualified to handle about 1-1/2 complete test programs.

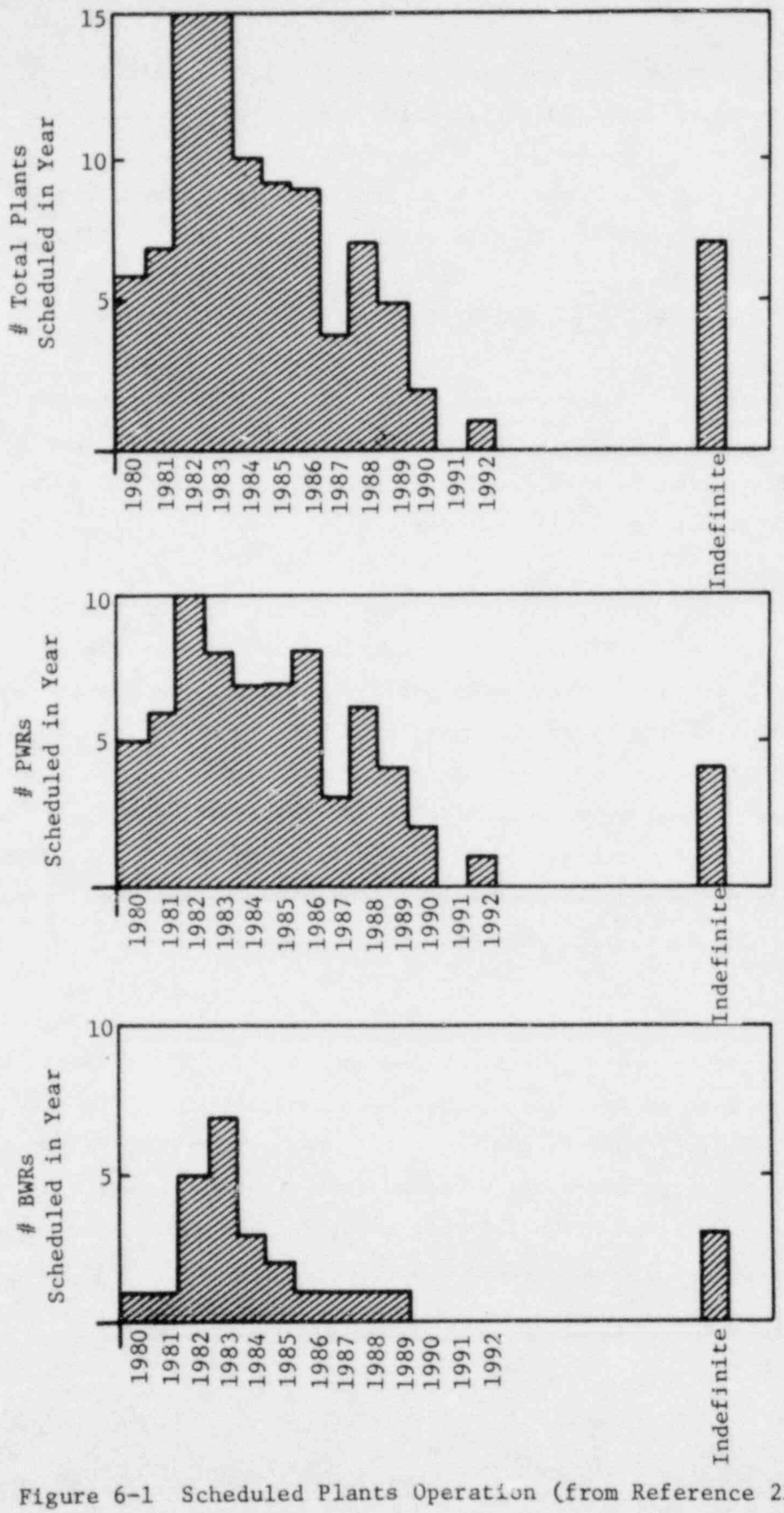


Figure 6-1 Scheduled Plants Operation (from Reference 23)

6.3.2 NRC Past and Present Involvement

In the past, NRC has had no qualification test or direct-witnessing program. NRC's nearest related programmatic activities consisted of the following:

- NRR reviews the licensee's SAR commitments for qualification of safety-related equipment and in some instances reviews special qualification documentation submitted by the licensee and generic reports provided by the licensee's contractors. In a few isolated instances NRC personnel have witnessed qualification tests which were required by NRC because of discovered deficiencies in qualification documentation.

- IE's vendor inspection program[24] requires inspection of safety-related equipment environmental qualification documentation at the manufacturing facilities. In essence this program verifies that qualification test procedures have been established and properly implemented and that the qualification satisfies the standards and special requirements imposed on the manufacturer by the licensee and/or his agent. To date this program has not been as effective as necessary, primarily because of the limited time and number of inspections, limited experience of the inspectors, and the fact that the tests are not witnessed.

- IE's on-site inspection program requires inspection of the licensee program covering review and acceptance of qualification documentation. These inspections essentially verify that the licensee has established a program and to a limited extent that the program is adequately implemented. The approach has produced limited success because of limited inspection depth associated with verifying that implementation is adequate. In many cases only certification reports are present at the site; i.e., the total qualification documentation is retained by the AE or manufacturer.

In a recent study[10] of the NRC quality assurance programmatic approach, the authors suggested three areas which would have the effect of increased and direct NRC involvement:

- Routine direct NRC inspection and testing of hardware be increased, and that data pertinent to quality decisions made in the construction and operation of a plant be evaluated by the NRC on a routine basis.

- Qualification testing be required for design verification when practicable.

- The NRC establish requirements and guidance for comprehensive qualification and proof test programs, similar in detail to the requirements and guidance for preoperational and startup testing programs. The guidance should include criteria for practicability.

In response to these recommendations, IE recently initiated a program that addresses independent verification testing of reactor construction materials and services. This program includes independent verification testing of environmentally qualified equipment within its scope but was specifically conceived as a small-scale (special case) activity (relative to the scope of this study). The new program is like Alternative 2 in that NRC has retained a commercial laboratory to conduct any tests specified in the scope of the contract.

It is to be concluded, then, that a program devoted to NRC review and witnessing of vendor/supplier environmental qualification tests will (effectively) be a new experience and undertaking for the NRC and its staff. A "gear-up" period to achieve a desired competence level will be required.

6.3.3 The Style of NRC Involvement: Who Should? How Should?

The who? and how? of NRC involvement in the review, witnessing, evaluation, and approval of vendor qualification tests are interesting and necessary questions, and relative to the evaluation of Alternative 3.

"Inspection" is the historical prerogative of the Office of Inspection and Enforcement (IE). On the other hand, the expertise in, and licensing responsibility for, equipment environmental qualification is spread throughout the NRC. While it is possible to continue this functional separation and still achieve a viable, responsive, program, it seems more appropriate to establish a dedicated staff to combine the inspection and licensing functions.

To effectively implement the alternative and assure direct NRC involvement, it is suggested that a separate dedicated staff responding to the appropriate Division Director be created to review, witness, evaluate, and approve safety-related equipment qualification (of all types and including environmental qualification). After approval of the qualification program and testing during the nuclear plant construction phase, the burden of activity would revert to other IE staff to be continued during plant operation. As required, the dedicated staff would provide continuing technical service during the plant lifetime, e.g., for ongoing qualification programs, replacement equipment, retrofits, etc.

A paired or triplet review team concept has certain appealing features. Besides the obvious benefit of co-mingled experience and technical judgment, there are benefits from sharing (i.e., rotating) on-site inspection visits and the reduction or avoidance of any illusion of NRC/industry collusion.

To effectively implement this alternative will require industry cooperation and a revised industry approach to qualification tests. It has been standard practice for industry to test, not so much for "qualification" but for type "development." That is to say, failures during tests were not of significance in the sense they could be used to develop the equipment type (and then retest). If, or when, the equipment type successfully completed the test regimen, the test would be used as the qualification program for that equipment type and be included as part of the licensing package. With on-site NRC witnessing of testing, "failures" may be uncomfortable to handle. The industry may want to assure itself of a successful test before NRC witnessing of it; that implies performing a second, essentially duplicate, test for benefit of NRC staff. In either case, the industry must clearly designate the test as a "qualification" test and then live with the results, whether pass or fail; and failures will cause concerns and costs.

To evaluate the test, it will be necessary for the NRC staff to review the associated test procedures and equipment documents before test conduct. This interaction, and possible interference, with the vendor is also unique. Clearly, the timeliness of NRC action affects the testing chain-of-events. The procedural format and schedule to implement Alternative 3 needs early consideration. The extent of NRC interaction with pretest qualification package "development" must be clearly defined.

As a companion issue, the type and level of on-site inspection required and desired must be determined. These inspections could range from unannounced aperiodic visits to the test laboratory, to full-time visits for selected parts of the test sequence (Table 3-3), to 24-hour coverage of the entire test sequence. The level-of-effort clearly depends upon the inspection schedule and format. Here again, industry cooperation in scheduling of tests must be available.

6.3.4 The "Unit Standard" Review Team

Unfortunately, under this alternative, each equipment test sequence will differ to some extent, which implies that the review team must address each test sequence as unique, with a full review and inspection. There are no major time shortcuts apparent, except that afforded by experience. Just how many test sequences can be handled by a team is dependent upon the specific tests, test schedules, location of the test facility, complexity of the safety-related equipment being tested, the kinds and levels of on-site inspection, industry cooperation with timely information, and many other variables.

Considering the general test sequence as outlined in Table 3-3, a complete test sequence requires approximately 70+ (working) days of test laboratory effort. This is quickly compounded by the estimated 20 generic equipment items for each complete test program and the estimated 25 programs before 1990, on the average of 2+ complete programs per year.

To begin the estimate of effort, consider that each test sequence requires 90+ (calendar) days for laboratory testing. It seems reasonable that pre- and posttest evaluations could double that time; that is, a judgment of a specific equipment item qualification would require 1/2 year from industry submittal of the package, on the average.

It is not likely that the 3-man team is fully-occupied during this 1/2-year period. Most likely, it could parallel its effort on more than one test sequence. At least initially, it may require the full-time effort of one-equivalent staff member to judge the pretest program submittals, a one-man equivalent effort to witness the actual tests, and a two-man equivalent effort to perform posttest analyses, evaluations, and acceptance. Assuming a 60-90-30 day split for pre-, during-, and posttest phases, the 1/2 year calendar effort requires 1/6-, 1/4-, 1/6-man-year of effort (or about 0.6 man-year total effort in 1/2 year or about 1.2 men/year). On that basis, the 3-man team can accomplish about 3/1.2 (or 2.5) test sequences per year. Considering 20 generic test sequences per program, the 3-man team can accomplish 2.5/20 (or 1/8) test program per year.

Since team efficiency will improve with experience (but is not likely to double), it seems reasonable to assume that the 3-man team can accomplish a 1/8 test-program/year initially, 1/6 test-program/year after 1 year, and 1/4 test-program/year after 2 years. On the average then, a 3-man team can accomplish about 1/6 test-program/year.

6.4 The Organizational Structure to Implement Alternative 3

Alternative 3 will be scoped on the basis of complete and blanket coverage by NRC-staff of all vendor qualification programs. Clearly, that is a rather massive undertaking, as was suggested at in Section 6.3. Just as clearly, this approach is absolutely responsive to the objective of "direct NRC involvement." At the same time, less (than total) review/witnessing could be accomplished and still be responsive and effective to the objective. Scaling of the overall effort is rather simple under this alternative since only (NRC) manpower is involved; the scaling of the tests' coverage translates directly into required manpower and costs. For example, if one-fourth of the tests are reviewed/witnessed, then one-fourth of the (full-coverage) manpower is required, and so on.

Alternative 3 is unlike Alternatives 1 and 2 since there are no facilities to construct and operate, no major contractors or subcontractors, and no test specimens to purchase. All activities are internal to, and integral with, the NRC itself and the regulation/licensing function. Even so, to implement the alternative will require a personnel training and development period; i.e., some period of time will be required for the alternative to reach full fruition. NRC-management commitment is also necessary to (1) establish the program, (2) insulate the staff from competing demands, and (3) provide a continuing sense of purpose for the staff.

It should be pointed out that when the dedicated staff is established, they should be devoted to all aspects of qualification of safety-related equipment, not to just environmental qualification. This would represent an efficient use of the staff potential, but would likely require some supplemental staffing. These supplemental staff have not been considered in the alternative and its evaluation. Perhaps up to 10 to 20 percent additional staff would be required.

Before continuing with this section, it is worth reiterating the "new ground rules" and pertinent points established in Section 6.3. They form the bases for the implementation and evaluation of Alternative 3.

- Industry sets the pace, kind, and quality of testing.
- The (approximately) 97 plants, now in the licensing process and committed to IEEE 323-1974, represent an estimated test load range of between 18 and 45 complete test programs. Assuming "middle" values, it can be expected that 25 equivalent test programs (i.e., 25 complete 20 test sequences of tests) will be conducted between 1980 and 1992.
- Major testing will begin almost immediately. By 1980, 1-1/2 test programs per year will occur; in 1983, 4 test programs will occur; beyond 1984, the test program rate will diminish uniformly through about 1992 (disregarding new plants, etc).
- A separate dedicated staff should be created to review, witness, evaluate, and certify these test programs.
- For any test program, a three-man team concept has interesting benefits beyond its numbers and shared work loads.

- Early consideration of very difficult NRC/industry relationships must be a major task in implementing the alternative. The effectiveness of the alternative depends, in large part, on clear understandings and cooperation with the nuclear industry.
- If full test program and test sequence coverage is desired, the 3-man team can complete about 1/6 test program per year.

6.4.1 The Formative Stage

By edict, NRC management can implement the alternative by directing existing staff to this effort. A capability is therefore instantly available to assure direct NRC involvement in industry qualification programs verification. But, to successfully implement complete coverage will require some preparatory planning and staff development, and direct NRC-management commitment. The level of effort is significant and will require displacement and/or hiring of staff. Initially, staffing will come from on-role qualification engineers who have the prerequisite background and experience. The first required management decision is to assemble, from these staff, into a dedicated divisional effort. These staff will not immediately address "qualification," but the mechanics, logistics, and interfaces problems inherent in the alternative. As the staff moves into qualification verification, the engineering disciplines will be supplemented by support and coordination staff.

To a first approximation, the implementation must be timed to meet the industry qualification programs pace. It is generally perceived by all parties that the Comanche Peak Station will be the first to undergo the full IEEE-323-1974 program and review. Unit 1 construction is about 70% complete and scheduled for commercial operation in 1981; qualification programs have therefore already started. But as discussed in Section 6.3.1, the activity will build to a peak in circa-1983, so there is time to carefully develop the alternative into a coherent plan.

It is reasonable to begin the activity with a branch of 10 people (and support). The duties of the staff would be to detail the alternative and its complete implementation. Within 6 months, a second branch

(10 people) would be added to begin dealing directly with qualification program review. Additional staff would then be added as needed to meet the demands of the programs pace. Within about 3 years, a full complement of staff would be available to handle the anticipated 4 full programs per year rate. Table 6-3 outlines this staffing schedule; the upper level of staffing of course depends on the "coverage" desired.

6.4.2 Staff Makeup

The staffing for Alternative 3 is somewhat unique. Besides the usual technical staff, it will be necessary to provide supplemental "coordinating" staff for its effective implementation. This is due to the complex and close industry relationships which must exist. The coordination staff will interact with the vendors to assure the correct document sequencing, to arrange and schedule on-site technical visits, and to perform any and all logistics functions. As the staffing becomes fully established, approximately 10% of them will serve in this coordinating capacity. For maximum efficiency, these personnel should be assigned to the technical branches to work directly with the cognizant engineering staff and for their direct relief.

The ancillary overhead costs to support the staff activity will be higher than average because of the on-site visits and associated travel required. On a per program basis, these can be estimated as follows, by assuming:

- 90 on-site inspection days per test
- 20 tests per program
- $40 per day per diem
- 5 travels per test
- $200 per travel round trip.

With these values, per diem expenses are $72K per program, and travel expenses are $20K per program, for a total of $92K per program. At the height of activity, at 4 programs per year, this cost reaches almost $375K per year of ancillary cost.

Table 6-3

Staffing Schedule for Alternative 3 to Achieve 100% Coverage

Year 1		Year 2	Year 3	Year 4
10 people 1 branch	20 people 2 branches	30 people 3 branches	50 people 5 branches	75 people 8 branches →

Year	Averaged Staff	Annual Staff Cost (K$)	Annual Programs Cost* (K$)	Cumulative Cost (K$)	Annual Programs Complete	Cumulative Programs Complete
1	20	1000	101	1101	1.1	1.1
2	40	2100	202	3403	2.2	3.3
3	60	3500	303	7206	3.3	6.6
4	75	4000	386	11,592	4.2	10.8
5	75	4500	386	16,478	4.2	15.0
6	60	3800	303	20,581	3.3	18.3
7	50	3500	258	24 339	2.8	21.1
8	35	2500	184	27,023	2.0	23.1
9	35	2700	184	29,907	2.0	25.1

*$92K per program

6.4.3 Sustained Level of Activity

Based on this complete coverage scenario, the staff will increase to its maximum level (of 75+) in about 3 years. The effort of this staff will be to monitor vendor tests; but in so doing, it will implicitly force some industry standardizations, particularly in test procedure and test methodology. This standardization will occur through program reviews by the NRC staff and commonalities in test program acceptability.

At the same time, the staff cannot do more than attain/assure the state-of-the-art in the early phases of Alternative 3. Beyond the peak testing years (circa-1983, -1984), there may be surplus trained staff available to define programs to extend the state-of-the-art. This is a logical extension of the alternative and its function. An entire branch (6 to 10 people) could be dedicated to this activity, supported by Research and Standards personnel.

It is also to be expected that the current nuclear plant test load will be supplemented by new plant orders; then, post-circa-1985, a continuing level of effort will be required for the forseeable future. Using the 1980-to-1992 era as an average, about 2 full programs per year are to be expected; that would require about 35 dedicated staff on a continuing basis.

6.4.4 Other Implications of the Alternative

The implications of the alternative extend beyond costs and manpower discussed above and are both positive and negative.

By nature of the overall program review process, the centralized NRC review will provide a measure of "standardization," particularly within the testing industry. Most likely, this will be achieved ex post facto, i.e., by industry understanding of NRC acceptability; but in the pretest program review, the NRC-staff could take a more direct and active role in establishing some standardization. This "standardization" would be available to the general industry as well.

The staffing estimates for this alternative are based on a full coverage scenario. Early in its implementation, decisions must be made on the techniques to be used in sampling of test results. The total NRC level of effort is directly related to these decisions, and judicious sampling and selection can substantially reduce the total effort required. The confidence level can still be maintained, if handled properly, with statistical techniques.

The alternative is limited to a "feed-forward" mode. Since the industry sets the pace, kind, and quality of testing, there is effectively no controllable feedback mechanism available. In a sense, the NRC, and in some sense the industry, cannot learn from experience; that is, a following test cannot be immediately affected by the prior test (although globally, some historical effect can be brought to bear in the long term). Similarly, the alternative does not allow for a directly controlled testing capability. "Independence" is then only achieved by independent witnessing, but not hands-on conduct, of the tests. These tests cannot be interrupted and/or restarted on the basis of new information or early test results, unless the tester or equipment owner recognizes the benefit. The NRC can only approve the test program in toto, which is effectively a pass/fail evaluation after the test is completed.

Without a directly controlled test capability, no "verification" of previous testing programs is possible. The status and acceptability of current testing must be acknowledged, until the alternative can be implemented; judgements as to the "grandfathering" of such testing must be addressed.

The alternative's ultimate success is dependent upon industry cooperation and scheduling. The mechanism to affect this cooperation must be clearly delineated and thought out. In this respect, it would be expedient to introduce the industry to the alternative as early as possible, during its implementation. It is to be expected that industry will generally regard the direct "looking over the shoulder" with alienation. Early resolution of the significance of "failures" in testing needs to be made; some method for allowing industry to retain a proprietorship over its own testing must be worked out. Without such assurances, the industry may feel forced to do repetitive, costly, duplicate tests exclusively for the benefit of the NRC inspectors (see also Section 6.3.3).

Alternatives 1 and 2 will likely have the affect of reducing the total numbers of actual tests that would be conducted to qualify safety-related equipment, but Alternative 3 could not have that effect. Under the former with their "universal test profile" feature, it would be judicious for the vendors/owners to umbrella their equipment within the universal profile to claim conformance and qualification. Alternative 3 does not have such a feature and this, coupled with the general competitive features of industry, effectively assures a total greater overall test effort.

6.5 Third-Party Efforts and Programs Certification

Within the context of "NRC review and witnessing of vendor tests," some other alternate--complementary or supplementary (depending upon the level of implementation)--concepts have been proposed and discussed. These generally can be categorized as third-party efforts or NRC certification of qualification programs.

The third-party effort would vest certain authority and responsibility in independent nationally recognized industry bodies. A close, and existing, example is the N-stamp e fort for mechanical apparatus under the purview of the ASME.[25] A logical body for safety-related equipment qualification would be the IEEE, which has a preeminent role in qualification standards development. Discussions between NRC and the IEEE were conducted previously (circa-1974) specifically on the point of third-party effort.[26] These apparently did not lead to fruition at that time.

More recently (circa-1978), these discussions were reopened between IEEE and IE staff.[27] Apparently IEEE has agreed to study and report on their view of conducting such a third-party effort. But the scope of such an effort is currently limited to QA aspects of safety-related equipment and does not actually extend to qualification per se.

To accomplish an Alternative-3-like effort by using a third-party would be a difficult, costly, and an extensive undertaking, with no existing parallels within the nuclear industry, or any other industry. On a reduced scale however, some effort may be appropriate to certify testing and test laboratories and to standardize test procedures and techniques. The third-party effort could only supplement the Alternative 3 objectives and the study objective, to afford direct NRC involvement in equipment qualification. The impact of the effort would be directly a function of its scope and level of implementation.

The Nuclear Power Engineering Committee (NPEC) of IEEE has formulated another suggestion relative to equipment qualification program certification.[28] Table 6-4 reproduces that suggestion from Reference 28. The approach recommended here is to have the NRC pass formally on individual qualification programs rather than as a part of a complete licensing package. The full-coverage implementation of Alternative 3, as outlined previously, has the same implicit result. A basic difference is that the alternative would also include direct NRC involvement by their review and witnessing of the actual testing.

The advantages of these efforts are a more central role for the industry, direct industry control over the qualification issues, a self-regulating feature held within the industry, and less direct NRC costs while still achieving a higher level of confidence. The impact on the overriding objective of direct NRC involvement clearly depends upon the specific features of a third-party effort. Almost certainly, such an effort could not be implemented in a sufficiently short time to relieve the NRC from their mandate; these efforts could be part of a long-term approach to safety-related equipment qualification to the extent that they parallel the specific needs of the NRC.

Table 6-4

Industry Suggestions (from Reference 28)

EQUIPMENT CERTIFICATION - AN ALTERNATIVE TO INDEPENDENT TESTING OF SAFETY-RELATED EQUIPMENT BY THE NRC

To the extent that the consideration of a government laboratory is motivated by concerns that some current qualification testing is inadequate and that such inadequacies may escape discovery during the qualification process, an alternative attack on the problem would be the review and certification of qualification programs by the NRC.

A certification program would include the following elements:

1. Documentation by an applicant (manufacturer) of

    a. The equipment to be certified
    b. The capabilities claimed
    c. The analyses and tests that form the basis of the claims in (b).

2. NRC review of the documentation, concluding with issuance of a certification or rejection of the application (with reasons given for doing so).

This approach includes the following advantages:

1. Certified equipment could be accepted with confidence by architect-engineers and utilities, without having to undertake a costly review of the qualification documentation.

2. Plant licensing would be simplified because the review leading to equipment certification would not have to be repeated. It would be necessary only to verify that the certified performance meets the plant requirements.

3. Exaggerated claims of qualification in the marketing of equipment would be diminished: claims not supported by certification would be suspect.

6.6 Evaluation of Alternative 3 Against the Criteria

Before detailed discussion of each criterion, Table 6-5 summarizes the scoring of the alternative; justification of the selected scoring is given in the criterion evaluation writeups below. Section 6.7 continues the criteria evaluation but with regard to a quasi cost/benefit format and with some discussion of relative criterion importance. Criterion with an asterisk (*) indicates a "core" criterion as described in Section 3.4.2.

Table 6-5

Alternative 3 Scoring

Criterion	Description	Score*
1	Level of NRC Involvement	7
2	"Immediacy" of the Alternative	8
3	Costs: Initial, Yearly, Long-Term	7
4	Direct Control of Prior-Tests Verifications	1
5	Flexibility	1
6	Degree of Control Available	2
7	Long-Term Use Potential	6
8	Staffing Levels Required from NRC to Implement Alternative	2
9	Historical/Chartered Function of the NRC	8
10	Dependence on the Supplier/Vendor	2
11	Conflict-of-Interest/Conflict-of-Participants-Interest	8
	Total Score	52

*1 -- most negative
5 -- neutral
9 -- most positive

6.6.1 Individual Criterion Discussion

(*) Criterion 1: Level of NRC Involvement: The level of NRC involvement is high, but not arbitrarily high. Successful implementation depends upon industry cooperation, or conversely, regulatory leverage. In either case, the type of NRC involvement also differs in this alternative; the NRC participates only in a reviewer/observer mode and is effectively removed from actual hands-on testing. The logistics of separated test facilities also makes the constant presence of NRC staff somewhat difficult. All in all, Alternative 3 does offer a substantial level of NRC involvement. The score is 7.

(*) Criterion 2: "Immediacy" of the Alternative: The alternative can be "implemented" by edict simply by a directive from NRC management. In some sense, it exists already in principle, within the licensing review group of NRR who are assigned the responsibility of evaluating environmental qualification programs and within the IE vendor inspection program which includes inspection of environmental qualification documents.

But to fully and successfully implement the complete alternative will require some preparatory planning and staff development, and some time. Its implementation must be timed against the pace of industry-generated qualification programs.

The alternative is overall strongly positive with respect to this criterion and is so reflected in the score of 8.

(*) Criterion 3: Costs; Initial, Yearly, Long-Term: This alternative requires no expenditures for capital equipment, subcontracts, or test equipment. The costs are internal to the NRC for manpower, travel, and support. Neither are there any long-term commitments. At the peak of activity, for a full-coverage scenario, the yearly cost estimate is approximately $4M+; this cost is flexible with the yearly work load. This cost is not prohibitive when compared with other major NRC budget programs.

An interesting feature of this alternative is that many more tests will need to be reviewed/witnessed than will be conducted under Alternatives 1 and 2. In a sense then, the overall long-term costs may turn out to be quite large for Alternative 3.

For immediately recognized benefits, the alternative is relatively low cost, and it is a positive feature with respect to the criterion with a score of 7.

Criterion 4: Direct Control of Prior-Tests Verifications: The alternative does not allow for this feature. The industry sets the pace, kind, and quality of testing. The score is 1.

Criterion 5: Flexibility: The alternative does not allow for this feature, and offers no benefit beyond NRC ability to affect programs. The score is 1.

Criterion 6: Degree of Control Available: The alternative does not specifically allow for this feature; the NRC role is to review and witness vendor tests. At the same time, if NRC is allowed to review the sequence of events constituting a complete program (Section 6.3.4), their judgments may lead to explicit, or implicit, "shifts" in the program by the vendor/tester. This is a form of control; the score is 2.

Criterion 7: Long-Term Use Potential: Since the alternative does not involve capital expenditures with tangible value, it has no long-term use potential in that narrowest aspect. On the other hand, specific NRC staff are available to be redirected to long-term needs, a positive factor. It is judged that the alternative is slightly positive with respect to the criterion, with a score of 6.

(*) Criterion 8: Staffing Levels Required from NRC to Implement Alternative: The entire staffing for this alternative comes from within the NRC itself. At the height of activity, and given the full-coverage scenario, an estimated 75 people (and support) will be required. In the long-term, 35 people may be required on a continuing basis. These represent a significant increase in NRC staffing, which is a highly negative factor in scoring to this criterion. The score of 2 reflects this strongly negative feature of the alternative.

(*) Criterion 9: Historical/Chartered Function of the NRC: Review of licensee and vendor programs is the prime function of the NRC organization as presently structured. Witnessing of actual tests is within the purview of the NRC, particularly a function of IE, but has not been extensively practiced to date, as described earlier in this chapter. Alternative 3 represents a direct exercise of the historical and chartered function of the NRC, as well as a practical extension of that function to increase on-site test witnessing. It is judged that the alternative is strongly positive with respect to the criterion with a score of 8.

(*) Criterion 10: Dependence on the Supplier/Vendor: As repetitiously stated, the industry will set the pace, kind, and quality of testing under this alternative. The NRC function is to review and witness the tests. The criterion is almost a restatement of the Alternative 3 ground rules. As such, the alternative is highly negative with respect to the criterion as reflected in the score of 2.

(*) Criterion 11: Conflict-of-Interest/Conflict-of-Participants-Interests: A principal concern in this alternative is to avoid any (illusion of) NRC/industry collusion. A paired, or preferably a triplet, review team concept has certain advantages here. Since direct NRC participation is involved, and not through a second or third party, the alternative is favorably compatible with the criterion. The score is 8.

6.6.2 Alternative 3 "Scoring" Summary

Like Alternative 1, Alternative 3 is not neutral in its scoring to the criteria; the total unweighted score is 52, out of a possible 99. It offers as its primary advantages its consistency with the historical and chartered NRC mission, no illusion of conflict-of-interest, and its "immediacy" of implementation. Negatively, it demands large staffing from within the NRC and allows no direct control or flexibility.

Chapter 7 and Section 6.7 continue the intra- and interalternatives evaluation, respectively. Section 6.7 concentrates on the core criteria as previously defined.

6.7 Alternative 3 Against the Core Criteria

The 11 criteria discussed in previous sections represent the chosen set of considerations for intra- and interalternative comparisons. But a narrower set would be actually applicable if there is no deviation from the specific tests and there is no long-term need identified. The "core criteria" eliminate the advantages of flexibility, direct control, etc. Table 6-6 lists these and the Alternative 3 scoring; the total score is 42, out of a possible 63. It should be noted that against the (4 remaining) criteria not considered to be "core criteria," Alternative 3 scores very poorly (10 of 36 points).

Table 6-6

Alternative 3 Scoring Against "Core Criteria"

Criterion	Description	Score*
1	Level of NRC Involvement	7
2	"Immediacy" of the Alternative	8
3	Costs: Initial, Yearly, Long-Term	7
8	Staffing Levels Required from NRC to Implement Alternative	2
9	Historical/Chartered Function of the NRC	8
10	Dependence on the Supplier/Vendor	2
11	Conflict-of-Interest/Conflict-of-Participants-Interest	8
	Total Score	42

*1 -- most negative
5 -- neutral
9 -- most positive

The core criteria can be viewed as an (equally) weighted set; they could also serve for direct cost/benefit evaluations of the alternative. In summarizing Alternative 3, it offers immediacy of implementation and compatibility with the historical and chartered NRC function. It does sacrifice control and requires large numbers of direct NRC staff.

CHAPTER 7. INTERALTERNATIVE EVALUATION

The preceding three chapters have concentrated individually upon the three specific alternatives and evaluated each, internally, against the criteria. In this chapter, the alternatives will be cross-compared and interevaluated, and an "optimal" recommendation will be outlined. This will be preceded by a brief review of the study objectives and alternatives, an overview criteria comparison, a detailed review and comparison of the core criteria, and some discussion of other "intangible" factors.

7.1 Objectives and Alternatives, A Review

It is important here to recall the original directive statement[1] that initiated this evaluation:

> "Provide the Commission with an analysis of alternatives (including estimates of resource requirements and potential benefits) for conducting independent verification testing of environmentally qualified equipment which is required to operate in safety systems ..."

The IE plan[3] for the analysis of the three major alternatives available to the Commission effectively serves as the study implementing statement:

> "In essence, the plan consists of analyzing the following three alternatives each representing a course of action that will provide greater NRC involvement in equipment environmental qualification than presently exists.
>
> - NRC environmental test facility
> - NRC contracts environmental testing to existing DOE or independent laboratories
> - NRC review and witnessing of vendor tests conducted to meet NRC requirements.
>
> Combinations of these alternatives will be considered in search for the optimum method of monitoring and controlling the adequacy of equipment qualifications."

There is no ambiguity as to the "potential benefit" of these alternatives. They will provide greater NRC involvement in safety-related equipment environmental qualification. The NRC is viewed as a completely independent arbiter, with the quality of any verification (and qualification) test results directly relatable to the level of that direct involvement. The Commissioners directive[1] must be interpreted as demanding a high degree of independent assurance.

This study can not decide the "level-of-confidence" desired by the NRC staff or the Commissioners. Its only purpose is to formulate and formalize the trade-offs that must be made to achieve a final goal and level, and specifically, to detail the related and relative costs.

7.2 Initial Criteria Comparisons

Tables 7-1 and 7-2 summarize the scoring of the alternatives against the criteria outlined in Section 3.4 and as discussed in the three preceding chapters.

Against the 11 criteria, Alternative 1 (dedicated test facility) scores highest, and Alternative 3 (NRC review/witnessing of vendor tests) scores marginally lowest. Against the core criteria (Table 7-2), the relative scoring is almost reversed; Alternative 3 scores highest and Alternative 2 (contracts testing) scores lowest. The scoring seems to imply that no alternative offers a marked advantage over the others, especially when only the core criteria are considered. Alternative 1 gains its advantage through its direct control and flexibility features. Alternative 3 scores relatively well in immediacy, costs, and historical function. Table 7-3 emphasizes the relative differences in alternatives on a pair-by-pair basis.

Table 7-1

Summary Scoring Against the Criteria

		Scoring		
Criterion	Description	Alternative 1	Alternative 2	Alternative 3
1	Level of NRC Involvement	9	8	7
2	"Immediacy" of the Alternative	2	3	8
3	Costs; Initial, Yearly, Long-term	3	4	7
4	Direct Control of Prior-Tests Verifications	8	6	1
5	Flexibility	9	6	1
6	Degree of Control Available	9	4	2
7	Long-Term Use Potential	8	6	6
8	Staffing Levels Required from NRC to Implement Alternative	7	7	2
9	Historical/Chartered Function of the NRC	3	3	8
10	Dependence on the Supplier/Vendor	4	4	2
11	Conflict-of-Interest/ Conflict-of-Participants-Interest	8	3	8
	Totals	70	54	52

Table 7-2

Summary Scoring Against the "Core Criteria"

Criterion	Description	Scoring		
		Alternative 1	Alternative 2	Alternative 3
1	Level of NRC Involvement	9	8	7
2	"Immediacy" of the Alternative	2	3	8
3	Costs; Initial, Yearly, Long-term	3	4	7
8	Staffing Levels Required from NRC to Implement Alternative	7	7	2
9	Historical/Chartered Function of the NRC	3	3	8
10	Dependence on the Supplier/Vendor	4	4	2
11	Conflict-of-Interest/ Conflict-of-Participants-Interest	8	3	8
	Totals	36	32	42

Table 7-3

Pair-By-Pair Scoring Summary Against the Criteria

Criterion	Description	Alternatives 1	2	Alternatives 1	3	Alternatives 2	3
1	Level of NRC Involvement	9	8	9	7	8	7
2	"Immediacy" of the Alternative	2	3	2	8	3	8
3	Costs; Initial, Yearly, Long-Term	3	4	3	7	4	7
4	Direct Control of Prior-Tests Verifications	8	6	8	1	6	1
5	Flexibility	9	6	9	1	6	1
6	Degree of Control Available	9	4	9	2	4	2
7	Long-Term Use Potential	8	6	8	6	6	6
8	Staffing Levels Required from NRC to Implement Alternative	7	7	7	2	7	2
9	Historical/Chartered Function of the NRC	3	3	3	8	3	8
10	Dependence on the Supplier/Vendor	4	4	4	2	4	2
11	Conflict-of-Interest/ Conflict-of-Participants-Interest	8	3	8	8	3	8
	Totals	70	54	70	52	54	52
		124		122		106	

Since there is no clear advantage for any alternative singly, combinations of alternatives should be considered. Table 7-4 pairs the alternatives and shows the "advantage-score" by the pairing. The "advantage-score" is the absolute difference in the paired alternatives score, but an "advantage-score" is only allowed if (at least) one of the alternatives has an individual score of 6 or more; this latter feature assures that the paired combination only receives advantage points when the combination is strongly positive with respect to the criterion. (That is, there is no advantage to pairing if the pair is not positive with respect to a criterion; neither is there advantage in combination unless the alternatives are complementary.)

This method of scoring highlights some individual criterion results. The "level of NRC involvement" (Criterion 1) is high for each alternative separately and therefore cannot be much improved by combination; this is also true for the "long-term use potential" (Criterion 7). By contrast, all alternatives suffer almost equally with respect to Criterion 10; none score higher than 4 individually.

The aggregate combinatorial scores are also revealing. There is no advantage to the combination of Alternatives 1 and 2 for either the inclusive, or core, criteria set. On the other hand, the combinations of Alternatives 1 and 3 and 2 and 3 suggest that these are highly complementary sets. Their respective advantage-scores to the core criteria are large, but essentially identical; but if the inclusive criteria set is considered, this analysis would suggest that a combination of Alternative 1 and 3 is most favorable.

7.3 Detailed Comparison and Summary of the Core Criteria

7.3.1 Criterion 1: Level of NRC Involvement

All alternatives provide a very high degree of increased NRC involvement. This is obvious since the thrust of the Commissioners directive[1] was toward this objective. The scores of 9, 8, and 7, respectively for Alternatives 1, 2, and 3, suggest more a relative difference than an actual difference. This criterion is not a determinant among the alternatives.

Table 7-4

Advantage Scoring* Through Alternatives Combinations

Criterion	Description	All Criteria Combinations 1 & 2	1 & 3	2 & 3	Core Criteria Combinations 1 & 2	1 & 3	2 & 3
1	Level of NRC Involvement	1	2	1	1	2	1
2	"Immediacy" of the Alternative	-	6	5	-	6	5
3	Costs; Initial, Yearly, Long-Term	-	4	3	-	4	3
4	Direct Control of Prior-Test Verifications	2	7	5			
5	Flexibility	3	8	5			
6	Degree of Control Available	5	7	-			
7	Long-Term Use Potential	2	2	0			
8	Staffing Levels Required from NRC to Implement Alternative	0	5	5	0	5	5
9	H. torical/Chartered Function of the NRC	-	5	5	-	5	5
10	Dependence on the Supplier/Vendor	-	-	-	-	-	-
11	Conflict-to-Interest/ Conflict-of-Participants-Interest	5	0	5	5	0	5
	Totals	18	46	34	6	22	24

*"Advantage Scoring" is the absolute difference of the alternatives, but one (at least) of the alternatives must have a score greater than "6."

7.3.2 Criterion 2: "Immediacy" of the Alternative

Table 7-5 summarizes the implementation schedules for the three alternatives. The table entries assume that each has a mandate to start immediately. For Alternative 1, this assumption ignores the usual and normal frustrations and delays associated with line-item Congressional budget entries for major construction projects. Even so, Alternative 1 requires about 5 years to achieve first test results and almost 9 years to complete the equipment backlog tests. Alternative 2 offers some time compression; but even so, it requires almost 3 years to achieve first test results and almost 5 years to complete the equipment backlog tests.

Alternative 3 is not directly comparable since it does not have the same milestones and objectives. Rather a commitment to this alternative implies a continuing commitment (assuming 100% coverage level) to full-coverage on-site inspection of all future industry qualification programs using dedicated NRC staff. In the narrowest sense, this alternative can be implemented immediately through a strong NRC management commitment and directive. To fully and successfully implement the complete alternative will require some preparatory planning and staff development, and some time. Its implementation must be coordinated with the pace of industry-generated qualification programs; under that influence, full-coverage implementation requires about 3 years.

7.3.3 Criterion 3: Costs: Initial, Yearly, Long-Term

As implied in Table 7-5, Alternatives 1 and 2 suffer with regard to costs in four respects. First, costs during the alternative implementation phase are not immediately offset with results and these costs grow yearly. For Alternative 1, these costs are associated with design, construction, and staffing. For Alternative 2, these costs result from staffing and subcontractor organization. Second, the direct costs to conduct the tests are borne within the alternatives and are relatively large over the tests (limited) duration. Third, the cost of test specimens is a direct expense. Fourth, the test facility and staffing (Alternative 1) or the major contractor and subcontractors staffing (Alternative 2) represents a long-term cost commitment competing for funding with other NRC programs/dollars.

Table 7-5

Alternatives Implementation

Year	Alternative 1	Alternative 2	Alternative 3	
1	Operator/site selected	Master contractor selected	Immediate implementation (by edict)	
2	AE selected	RFQ's	Staff Buildup Period	Test Program Reviews, Pacing Industry
3	Facility construction begins	Subcontractor(s) selected Equipment arrives ←First test begins		
4	Facility complete	Testing	←Full-Coverage Implementation	
5	Equipment arrives ←First test begins	←Backlog tests complete	Test Program Reviews, Pacing Industry	
6				
7	Testing	Long-term Use		
8				
9	←Backlog tests complete			
Beyond	Long-term Use			

Alternative 3 is uniquely different. It requires no expenditures for capital equipment, subcontracts, or test equipment. The costs are internal to the NRC for staff, travel and support, and there are no long-term commitments involved. A peculiar feature of this alternative is that many more tests will need to be reviewed/witnessed than will be conducted under Alternatives 1 and 2; in that sense, the overall long-term cost commitments are large.

Cost estimating is an inexact art at best. Nonetheless Table 7-6 attempts to estimate and compare the alternatives' costs on yearly and cumulative bases. The side-by-side comparisons are very interesting. Alternative 2 would require an estimated $17M (through year 5) to complete the equipment test backlog. Alternative 1 would require an estimated $43M (through year 9) to complete the same backlog, but that includes an $8M facility. Alternative 3 is relatively expensive, only because the total test load, to review and witness, is very large. Through year 4 (and 10+ programs), the cost is an estimated $11.5M; through year 9 (and 25+ programs), the cost is estimated to be $30M.

To reiterate, Alternative 3 is based on a complete-coverage scenario in which the competitive nuclear power industry will set the pace, kind, and quality of testing. If less than full-coverage is selected, the costs of Alternative 3 are proportionally reduced. (Complete coverage has been presented here to allow direct comparison with Alternatives 1 and 2.)

7.3.4 Criterion 8: Staffing Levels Required from NRC to Implement Alternatives

Direct NRC manpower to initiate and guide Alternative 1 or 2 are low, estimated at four full-time-equivalent personnel; this is effectivley a (small) branch function. Some additional NRC staff (estimated at 10 FTE) would also be required to serve as reviewers of the generated information, but this is the current function of NRC in regulating and licensing activities and does not represent a new, or dedicated, or increased function.

Table 7-6

Alternatives, Yearly/Cumulative Costs (K$)

Year	Alternative 1 (Phase I) NRC Staff	Alternative 1 (Phase I) Contractor Staff	Alternative 1 (Phase I) Other	Alternative 1 (Phase I) Total	Alternative 1 (Phase I) Cumulative Totals	Alternative 2 NRC Staff	Alternative 2 Contractor Staff	Alternative 2 Other	Alternative 2 Total	Alternative 2 Cumulative Totals	Alternative 3 NRC Staff	Alternative 3 Travel and Support	Alternative 3 Total	Alternative 3 Cumulative Totals
1	200	200	250	Total = 650	650	200	222	--	Total = 422	422	1000	101	Total = 1101	1101
2	220	900	500	Total = 1620	2270	220	918	--	Total = 1138	1560	2100	202	Total = 2302	3403
3	250	1400	1800	Total = 3450	5720	250	1542	700	Total = 2492	4052	3500	303	Total = 3803	7206
4	275	2200	5800	Total = 8275	13,995	275	1900	6800	Total = 8975	13,027	4000	386	Total = 4386	11,592
5	325	3450	709	Total = 4484	18,479	300	2000	5500	Total = 7800	20,827	4500	386	Total = 4886	16,478
6	375	3600	1188	Total = 5163	23,642						3800	303	Total = 4103	20,581
7	425	3925	1330	Total = 5680	29,322						3500	258	Total = 3758	24,339
8	500	4325	1475	Total = 6300	35,632						2500	184	Total = 2684	27,023
9	575	4750	1440	Total = 6765	42,397						2700	184	Total = 2884	29,907
Beyond	650	5225	2147	Total = 8022		325	2300	1200	Total = 3825		2900	184	Total = 3084	

The entire staffing for Alternative 3 comes from within the NRC itself. At the height of activity, and given the full-coverage scenario, an estimated 75 people (and support) will be required (20 people after year 1, 40 after year 2, 60 after year 3 and 75 after year 4). Thirty-five people may be required on a continuing basis.

There is little historical precedent for internal NRC staffing increases of this magnitude. Almost certainly, Alternative 3 could not be as fully implemented as presented in the study. It is, nonetheless, attractive since it can be scaled to meet the independent verification needs demanded, within the resources available.

7.3.5 Criterion 9: Historical/Chartered Function of the NRC

Direct involvement in qualification verification tests would be a new experience for the NRC, under either Alternative 1 or 2. Alternative 3, on the other hand, merely represents an exercise of the prime function of the NRC organization as historically structured, namely, the review and witnessing of licensee and vendor programs.

To select Alternative 1 or 2 is to realize that all tests and results are directly available to the general public and are subject to scrutiny and interpretation. This will pressure all participants to an even greater degree than that which currently exists. There will be little opportunity to use engineering judgment in the test results or to account for "grey" areas in a normal scientific fashion; i.e., any test result will be viewed as only pass/fail by some interested parties.

Although these tests are not intended to be qualification tests (as distinguished from verification and/or research tests) new licensees may attempt to umbrella their equipment and claim qualification through them. Alternative 1 or 2 would then require careful on-going attention to clearly distinguish its goals and objectives and industry relationships.

Even before this study was completed, the nuclear power industry reacted negatively to it and/or to its application. Their comments, from Reference 28, emphasize some concerns relative to this criterion, (Table 7-7).

7.3.6 Criterion 10: Dependence on the Supplier/Vendor

It is clear that any alternative selected cannot entirely avoid the criterion statement of concern. More than likely, it will be necessary (on occasion) to use implicit, or explicit, regulatory "clout" to accomplish overall aims and schedules.

For either Alternative 1 or 2, this fact is manifested in that the verification tests depends upon the timely supply of equipment for testing. This implies two separate uncertainties. First, vendor supply of a one-of-a-kind item is normally subject to large delivery schedule slippages and uncertainties. Second, the satisfactory certification that the vendor has supplied the actual "type" to be used in the field is a concern. By way of contrast, this latter concern is lessened where, and if, a test item can be selected directly from a larger order of such equipment; but this implies substantial effort to conduct tests in concert with equipment deliveries to ultimate users and as a result to be somewhat "at the mercy" of these users and vendors.

Alternative 3 is unique in this respect however. The industry will set the pace, kind, and quality of testing under this alternative; the NRC function is to review and witness these tests when and where conducted. Thus the alternative is directly "at the mercy" of the nuclear power industry, except that the NRC holds the licensing authority.

7.3.7 Criterion 11: Conflict-of-Interests/Conflict-of-Participants-Interests

This is a particularly interesting feature of the alternatives. Alternatives 1 and 3 can accommodate this criterion reasonably well, but through differing techniques. Alternative 2, on the other hand, may have some particular difficulties.

Table 7-7

Industry Response to Directive 5 (from Reference 28)

DISADVANTAGES OF ESTABLISHING FACILITIES FOR INDEPENDENT TESTING OF EQUIPMENT REQUIRED TO OPERATE IN SAFETY SYSTEMS

1. The capabilities needed to design, build and operate the required testing facilities can be gained only through experience, which currently is available primarily in industry. A government laboratory would have to gain these capabilities before undertaking verification testing; otherwise, its results might not be reliable. However, it would probably take a number of years before a new government laboratory would achieve the level of performance already available in industry.

2. For the NRC to verify qualification it would have to accept responsibility for the qualification of equipment within a plant. This seems contrary to the concepts of a regulatory body as an overseer and could put them in conflict of interest position.

3. To establish a testing facility would be a waste of taxpayers money since the NRC would duplicate tests already conducted by industry.

4. It is anticipated that if NRC goes into independent verification testing of environmentally qualified equipment which is required to operate in safety systems a great amount of additional confusion will result. Qualification testing requires varying amounts of engineering judgement throughout the process and unless the original test plan is used by the NRC, independent verification would be difficult if not impossible to accomplish. Resolving conflicts between industry tests and NRC sponsored tests would be chaotic.

5. The independent verification would extend the licensing process and represent delays to industry and the public while NRC and the testing laboratory conduct the verification program. The NRC staff would have to review independently the safety function and requirements for each safety related piece of equipment and component within a plant, establish its own acceptance criteria, prepare test specifications for the testing facilities, review and approve the test facility's test plans/procedures, witness the tests, review the reports, certify qualification and maintain all the qualification records. A formidable task that would certainly delay plant start-up process. Again, resolution of conflicts would be a time consuming nightmare.

6. The NRC facility would eventually become the sole source of device qualification consequentally eliminating another element of free enterprise in favor of a governmental operation, at additional expense to the taxpayer.

An NRC owned, or directly controlled, dedicated test facility (Alternative 1) substantially precludes conflict-of-interest charges and eliminates any conflict-of-participant-interest concerns. By avoiding subcontracting and subsubcontracting, "at-arms-length" transactions are easier to maintain. Similarly, there is no involvement of contract test labs (i.e., industry) where NRC-industry and industry-client relationships are mutually exclusive and thus jeopardized.

A principal concern in Alternative 3 is to avoid any (illusion of) NRC/industry collusion. A paired, or preferably a triplet, review team concept has certain advantages here. Some benefit is also obtained since direct NRC participation is involved, and not through a second or third party.

By subcontracting to third parties, it becomes increasingly more difficult to maintain "at-arms-length" transactions. It is particularly true in the case of Alternative 2, where subcontracts would be placed with the same commercial laboratories that perform tests for the nuclear industry which are, in turn, regulated by the NRC. This "daisy-chain" effect gives the illusion (even when untrue) of "conflict-of-interest."

Similarily, the commercial laboratories recognized some difficulties and expressed some reluctance in their survey/questionnaire responses with respect to their client relationships. It remains to be seen whether the commercial laboratories can even be persuaded to bid to the subcontracts.

Finally, in the industry response to Directive 5, Table 7-7 and Reference 28, concerns were expressed relative to this criterion.

7.4 The Intangible Factors

In the preceding chapters, and particularly in Sections 5.4.6, 6.4.4, and 6.5, certain complicating and intangible factors have been discussed as they separately relate to the individual alternatives. These were not presented to indicate the futility of the study, nor its alternatives nor objectives. Rather, they are considerations to be addressed as followup to this work and which serve to color the alternatives and the ultimate suggested course of action. A sampling of these intangible factors are summarized below.

In selecting the criteria and core criteria by which to evaluate the alternatives, there was an extension beyond the narrower objectives of the NRC directive[1] and the IE implementing plan.[3] This is appropriate for the study, but they also represent opportunity to the reader to examine the need for long-range goals and uses of any alternative, in light of its associated cost and quality of results. It is ultimately up to NRC management to decide the necessary followup to this effort. The criteria are but one tool to aid in that process.

Industry approaches to equipment qualification will be strongly influenced by these alternatives if adopted. Under Alternatives 1 and 2, it would behoove the industry to umbrella their testing/analyses under the "universal" test profile and to select only that equipment that "passed" the NRC verification tests; there are dangers in both eventualities and they tend to discourage equipment development and industry competition. In the extreme, there may be less incentive for industry to do any additional testing.

Alternatives 1 and 2 would likely serve as a (forced) "standardization" mechanism, particularly for test program and test procedure development. This "positive" effect would be maintained (at some level) beyond these verification tests and be available to general industry testing. But, especially in Alternative 2, this feature may be preferential if not all test facilities are upgraded, even those not directly subcontracted for verification tests. In fact, the direct subcontracting to a commercial laboratory has an implied NRC acceptability of the facility and an associated (intangible) competitive advantage in the marketplace. The legal implications of "contractual use of existing test facilities" is an area which may require additional consideration.

Actual testing by NRC, under Alternatives 1 and 2, has several interesting aspects which would need to be addressed. The real and conceptual differences between qualification and verification testing may not be precisely distinguishable in all cases; the industry, through NPEC, has also raised the point[28] that

> "For the NRC to verify qualification it would have to accept responsibility for the qualification of equipment within a plant."

It is the intent of Alternatives 1 and 2 to do verification tests on equipment already qualified by industry. However, because of the envelope profile approach that would have to be adopted, there will be "margin" between the verification tests and the appropriate qualification test. In subsequent usage, the verification test could be used as qualification tests by industry; such usage should be discouraged.

Since commercial industry facilities will be subcontracted under Alternative 2, there is opportunity to arrive at differing results for same-type equipment at the same test laboratories. This could be awkward for the laboratories and thought should be given to this eventuality; it may preclude some necessary industry participation in order to protect and assure long-standing industry-laboratory relationships. Also during the verification tests, these facilities are not available for other commercial users. The effect of NRC tests is to delay and upset the normal industry routine; dependent upon the exact test timing, this represents a, greater or lesser, direct real cost to the nuclear industry in general.

All of these alternatives, but particularly Alternative 3, will benefit from direct and positive industry cooperation and scheduling. Whatever alternative, or combinations, are eventually selected, it is imperative that the industry be involved from the earliest and that all parties perceive the long-range goals and benefits.

A third-party effort would seem to have no immediate impact relative to the aims of this study. In the long-term, and with some restructuring to include more than QA as its objective, a third-party effort could provide complementary support and even relief to the NRC staff.

7.5 Suggested Course of Action

As in all complex issues, the objective of increased NRC involvement in equipment environmental qualification and/or verification does not lend itself to a single, or even an, unambiguous solution. But in review of the objectives of the directive, the history of equipment qualification and its projected future, and the inherency of the alternatives, there appears to be two paramount features: immediacy and continuancy. Immediacy is, at least, dictated by the recent and increasing concerns over prior qualification programs, by the urgency and even mere existence of the Commissioners directive, and by the advent of qualification programs committed to IEEE-323-1974.[13] Continuancy is dictated by the normal industry-evolution of equipment as based in historical experience and by many remaining "issues" in equipment qualification.[29]

The combination of alternatives to meet the concerns for immediate response and effort and to provide the framework for the long-term approaches is the obvious conceptual solution. From the previous sections of this chapter, it would seem prudent to select primarily from Alternatives 3 and 1, and minimally from Alternative 2 (as a test "overflow" option).

Only Alternative 3 offers an immediate response mode; only Alternative 3 can be affected immediately and by NRC-management directive; only in Alternative 3 can a response be made commensurate with the pace of industry qualification programs. In addition, Alternative 3 is most easily graduated to accomplish a desired level-of-effort or level-of-confidence that is demanded.

The desirable feature of Alternative 1 is the dedicated test capability. Under this suggested combination, it is not reasonable to construct, equip, maintain, and staff a completely independent, stand-alone, facility. Rather existing capability (most likely at a DOE facility to avoid commercial relationship problems) can be used or upgraded as required.

The combinatorial alternative would then begin in the same manner as Alternative 3 (Section 6.4.1). It is reasonable to begin the activity with a branch of 10 people (and support). The earliest duties of this staff would be to detail the implementation of an Alternative-3-like feature and to further study and decide upon the ultimate level-of-activity under this mode. Within 6 months, a second branch (10 people) would be added as necessary to meet the demands of the program pace with a full complement of staff expected within about 3 years.

This immediate response mode will serve to overtake (and then assume the pace of) the industry programs as rapidly as possible. Many of the features of the plan and staff will parallel the Alternative 3 presentation in Section 6.4. However there are key differences. It is not anticipated that full-coverage of the industry test programs will be maintained or required. Second, the original nucleus branch will never be involved in qualification verification per se; rather, they will be involved in the overall program development and coordination for the future.

Following the (approximately) 6-month definition period, the nucleus branch will assume a second role. They will retain the function of establishing guidance for increased direct NRC involvement through review and witnessing of vendor test programs, and they will establish the routine and level of this involvement. But in addition, they will initiate the planning for an Alternative-1-like feature to parallel the review/witnessing program, provided this feature is found to be necessary.

This function would be initiated in the same manner as Alternative 1 (Section 4.4.1). The first-year activities would concentrate on facility-operator and site selection and on an in-depth detailing of the magnitude and ultimate capabilities of a dedicated verification test facility. Maximum use would be made of appropriate, available, non-commerical, facilities in this regard. Subsequent years would be spent in financial programming, NRC/operator liaison, and planning reviews/decisions. After construction and during full facility operation, the NRC-staff efforts would expand to accomplish the role of direct NRC involvement in the verification tests.

It is not appropriate here to fully describe the role, or magnitude, of the dedicated facility. That must be the function of the NRC staff as a coordinated-alternative plan is developed. As presently perceived, the facility would be used to spotcheck, pseudo-randomly, selected qualification test programs and to provide a flexible, dedicated, facility to accomplish the requirements of licensing and regulation. However, its testing capabilities would be limited (to reduce costs and to be devoted to verification) to an arbitrary and small-test level of perhaps six to eight tests per year. As an "overflow" option, consideration could be given to planning for subcontracting assistance (an Alternative-2-like feature).

Tables 7-8 and 7-9 outline one approach to an "optimal" solution, combining the best features of the three alternatives evaluated. It is important that a nucleus branch coordinate these efforts. Direct review and witnessing will be initiated by NRC staff immediately. Once this Alternative-3-like feature is established, it should be self-sufficient, with only indirect support required from the nucleus branch. Somewhat lagging this initial effort, the nucleus branch will establish the goals and magnitude of the independent test facility and proceed to establish it on a timely basis.

In this "optimal" alternative, full coverage of all vendor tests would not need to be witnessed by NRC staff, because the leverage of spotcheck evaluation/verification will be available through the independent test facility. Conversely, inclusive verification tests need not be conducted through the test facility, because the test load would be directly a responsibility of the vendors. Thus, the sharing and feedback opportunities tend to lower the costs through direct reduction in required NRC staff and a reduction in required test capability. This mutualistic relationship then conceptually produces optimality, while assuring direct NRC involvement, flexibility in operation and mode of operation, and long-term basis and benefit.

Table 7-8

Suggested "Optimal" Alternative

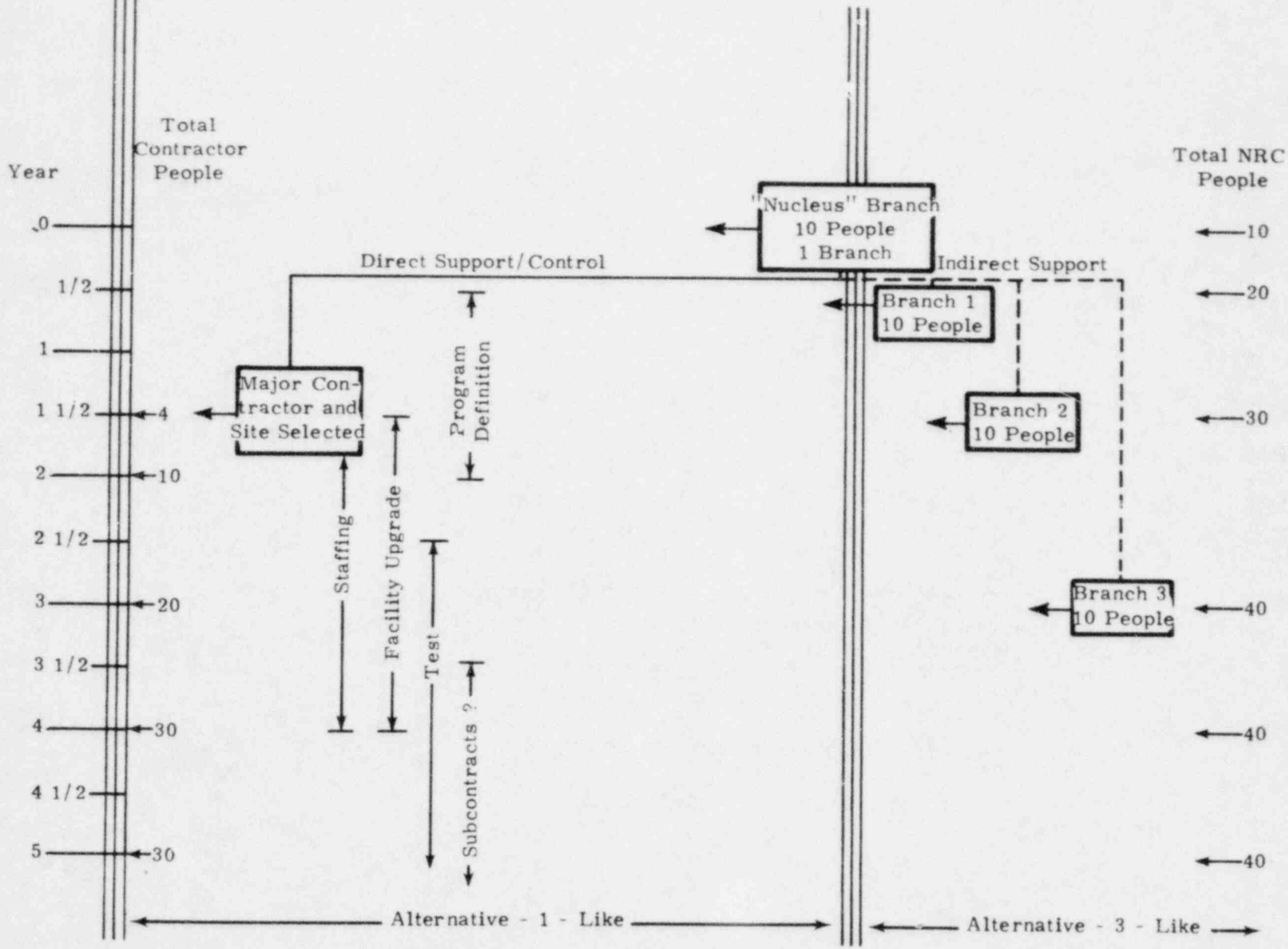


Table 7-9

Approximate "Optimal" Alternative Cost

	NRC (1978)		Contractor						
Year	People FTE	(K$)	People FTE	People (K$)	Upgrade (K$)	Test Support (K$)	Facility Maintenance (K$)	Annual Totals (K$)	Cumulative (K$)
1	19	950	--	--	--	--	--	950	950
2	30	1,500	4	200	250	--	--	1,950	2,900
3	37	1,850	15	750	750	150	50	3,550	6,450
4	40	2,000	25	1,250	500	300	150	4,200	10,650
5	40	2,000	30	1,500	--	300	300	4,100	14,750
Continuing	40		30					4,100	18,850

The costs associated with this "optimal" alternative are shown in Table 7-9. The major items identified, besides staffing, are facility upgrade ($1.5M), continuing test support and test equipment purchases ($300K/year), and facility replacement/maintenance ($300K/year). These are a function of the program definition phase of the effort, and will be adjusted during this phase. In any case, the facility upgrade should be a small fraction of the "dedicated" facility costs outlined in Chapter 4 and in Appendix B. On a continuing basis, staffing costs make up the majority (about two-thirds) of the yearly costs. Thus adjustments in facility and associated costs will only marginally affect overall cost commitments.

In comparing the Table 7-9 values with the separate costs of the alternatives (Table 7-6), this "optimal" alternative tends to most closely parallel the Alternative 3 costs. Yet it provides the Alternative 3 advantages along with many desirable features of Alternative 1. It should be clearly stated that in describing this as an "optimal" alternative, "optimal" refers most accurately to the concept, and less accurately to the actuality as presented; its final form is the business of the nucleus branch as directed by NRC management.

CHAPTER 8. SUMMARY AND CONCLUSIONS

There is no ambiguity as to the potential benefit of the alternatives evaluated in this study. They will provide greater, and direct, NRC involvement in safety-related equipment environmental qualification.

Just as clearly, there are costs and commitments associated with these alternatives not currently accommodated within the NRC budget and staff. This study cannot decide the level-of-confidence in equipment qualification and verification desired by the NRC staff or the Commissioners. Its purpose is to stimulate preliminary thinking and to formulate and formalize the trade-offs that must be considered to achieve that final goal and level, specifically by detailing the related and relative costs.

The three milestone alternatives (Dedicated Test Facility, Contracts to Existing Test Facilities, and NRC Review and Witnessing of Vendor Tests) represent realistic and bounding constraints, but are not individually optimal. Each offers real advantages and disadvantages when weighed against the evaluation criteria.

This study also illustrates the magnitude and immediacy of the equipment environmental qualification issue. The first plant (Comanche Peak), subject to IEEE-323-1974, has already begun the formal qualification review process. And it is estimated that this activity will reach a maximum level circa-1983, based on the schedule for new plant operations.

Beyond the data base and issues within the full report, there are three specific recommendations:

- A dedicated autonomous NRC staff, at least at a Branch level, be established immediately to be responsible for reviewing, witnessing, evaluating, and approving all safety-related equipment qualification programs.

- Within 6 to 12 months after its inception, the dedicated activity should be supplemented with sufficient additional staffing to continue this study, and to define and implement the longer range activities.

- Strong consideration should be given to the "optimal" alternative outlined in this report, a combination of Alternatives 1 and 3.

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3. Letter E. Volgenau (IE) to the Commissioners, June 14, 1978, "Plan for an Analysis of Alternatives for Conducting Independent Verificaton Testing of Environmentally Qualified Equipment."*

4. Letter J. Sniezek (IE) to J. Hickman (SLA), dtd June 2, 1978, with enclosure.*

5. Letter J. Hickman (SLA) to J. Sniezek (IE), dtd June 5, 1978.*

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*Available in the NRC Public Document Room for inspection and copying for a fee.

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*Available in the NRC Public Document Room for inspection and copying for a fee.

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*Available in the NRC Public Document Room for inspection and copying for a fee.

APPENDIX A

Equipment Backlog,
UEC Report

united engineers & constructors inc.
30 South 17th Street.
Post Office Box 8223
Philadelphia, Pa. 19101

December 28 , 1978
US-00036
File: 1.1
Cateogry: TECH.

Mr. J. B. Ayers
Purchasing Organization 3721
Sandia Laboratories
Albuquerque, New Mexico 87115

Dear Mr. Ayers:

Sandia Laboratories
Job Order No. 6602-002
Class 1E Equipment Table

Enclosed please find the table of Class 1E Equipment. The table includes a list of generic Class 1E equipment, manufacturer, model number, physical size, number of test specimen required and estimated cost. An explanation of each of these columns as well as a job summary is also attached.

In this revision we have included the number of test specimen required and an estimated cost of each generic piece of equipment.

By copy of this letter, we are forwarding a copy to Mr. G. Dowd for YAEC's review.

If you have any questions, please do not hesitate to call.

Very truly yours,

S. Kasturi
Project Manager

SK:JFB:egc
Attachment
cc: Messrs. L. Bonzon - 3L with 3A
G. Dowd - 1L with 1A
J. Ayers - 1L
W. Rutherford - 1L with 1A
J. Niemkiewicz- 1L with 1A

SUMMARY

On July 10, 1978, UE&C was authorized to provide support for the verification testing alternatives study being conducted by Sandia Laboratories for the U.S. N.R.C. . The attached list includes those items in UE&C's scope which are as follows:

1. Equipment: Definition of 27 Class 1E generic pieces of equipment that are used in typical Light Water Reactor (LWR) plants and located in an environmentally sensitive area
2. Manufacturer: For each generic Class 1E equipment, a limited list of manufacturers is shown.
3. Model Numbers: Manufacturer model numbers recommended by UE&C for testing are listed.
4. Physical Size: An envelope size or range of sizes for each generic piece of equipment or manufacturer's model where they differ
5. Number of Test Specimen Required: Quantity recommended by UE&C for testing each generic piece of equipment
6. Estimated Cost - Unit: Average unit estimate cost for each generic piece of equipment
7. Estimated Cost - Total: Average unit estimate cost times number of test specimen required

Explanation of Class 1E

Equipment Table

The attached table of Class 1E equipment lists information for the verification testing alternative study being conducted by Sandia Laboratories for the U.S. N.R.C. . Those items in UE&C's scope are: list of equipment, manufacturers, model numbers, physical size, number of test specimen required and estimated cost. Below is a further explanation of each column on the table:

1. Equipment: Definition of generic Class 1E equipment located in an environmentally sensitive area. This area is defined as where there is a potential for a hostile environment generated as a result of a high energy pipe rupture. Beside equipment located in containment, equipment located in the pipe tunnels and the Primary Auxiliary Building equipment vault is addressed in this list due to the potential for a hostile environment. This additional equipment, namely, airborne radiation monitors, hydrogen analyzers and 5 KV cable is identified as being outside containment in the remarks column. In total, 27 Class 1E generic pieces of equipment used in typical Light Water Reactor (LWR) plants are identified.

2. Manufacturer: For each Class 1E generic piece of equipment, a limited list of manufacturers is shown. To keep the size of the project to a manageable size, only 3 to 5 vendors are listed for each generic piece of equipment. Based on UE&C's past experience, this list of manufacturers together supply approximately 90-95% of the market.

3. Model Numbers: Manufacturer model numbers recommended by UE&C for testing are listed. This list does not contain every Class 1E model supplied by the manufacturers, but only those model numbers or types which differ in material and/or operation.

   It was from this list of manufacturers and model numbers that inquiries were sent out to obtain an estimated price. Vendors were invited to submit prices for other models which are also used in nuclear safety applications. Based on vendor responses a few model numbers have been added and changed.

4. Physical size: An envelope size rounded up to the nearest inch is listed for each generic price of equipment. Since some manufacturer's equipment size or individual model size differ significantly, individual sizes are listed in these cases.

   A range of sizes is given for actuators, terminal blocks, enclosures, terminal lugs and motors because sizes differ with valve size, number of poles, use of enclosure, type of wire and horsepower of motor, respectively.

5. Number of Test Specimen Required: Quality recommended by UE&C for testing each generic piece of equipment. This quantity is obtained by adding together the manufacturer model numbers for each generic piece of equipment. For the specimen number the quantity of manufacturers has been limited based on past experience Manufacturers not included are few and noted by a '*' in the table.

6. Estimated Cost - Unit: Average unit estimated cost for each generic piece of equipment. The cost was obtained using the following criteria:

   a. Average price from quotes submitted in response to UE&C's inquiries.

   b. The high price for each generic piece of equipment was omitted in this average because it was felt that the bid was not seriously reviewed by the manufacturer or full price of initial qualification was included.

   c. Due to the fact that each manufacturer was asked to note if the price included Class 1E qualification, seismic qualification and all quality assurance requirements, prices were generally taken from manufacturers that responded yes to all three questions. The exceptions are noted in f and g.

d. Price is based on 1978 dollars. BLS indices adjustment can be used to obtain future prices.

e. Allowance was added to each price of equipment to include special documentation, quality assurance procedures, welding procedures and other special technical requirements that UE&C requires on all Class 1E equipment. Additional price was based on UE&C past experience.

f. Pneumatic actuators and enclosures are non electrical (therefore, non Class 1E) but nuclear safety related and vendors do not address Class 1E qualification. UE&C has included an allowance proportional to the quoted vendor price based on past experience for safety qualification testing.

g. Pressure switches and rotameters have not been qualified by any manufacturers and as noted in 'f' above a proportional price has been also added for Class 1E qualification procedures.

7. Estimated Cost - Total: Unit estimated cost listed in column '6' times number of test specimen required in column '5'.

Where equipment differs significantly as in terminal lugs, 5KV cables and penetrations separate quantities of test specimen required as well as a separate estimated cost is listed.

For terminal blocks and enclosure where the number of poles and size vary significantly, a range of prices is listed.

CLASS IE EQUIPMENT TABLE

EQUIPMENT	MANUFACTURER	MODEL NUMBER	PHYSICAL SIZE**	NUMBER OF TEST SPECIMEN REQUIRED	ESTIMATED COST UNIT	ESTIMATED COST TOTAL	REMARKS
1. Transmitters	Barton	763 764	5"h x 5"w x 8"d	11	$ 2,000	$ 22,000	
	Rosemount	1153DP 1153HP 1153AP 1153GP	9"h x 5"w x 5"d				
	Westinghouse	Veritrak 76	5"h x 5"w x 8"d				
	Foxboro	E11GM E11AM E11DM E13DM	14"h x 7"w x 7"d				
2. Actuators (Electric)	Limitorque	Series SB Series SBD Series SMB	14"h x 41"w x 21"d to 22"h x 41"w x 21"d	5	$ 3,000	$ 15,000	
	Rotork	NA1 NA2					
3. Actuators (Pneumatic) (Not IE)	Matryx	26072-SR60	11"h x 60"w x 8"d	7	$1,500	$10,500	Due to the fact that these actuators are not electric (therefore not IE), the estimated cost includes an allowance proportioned to the price based on UE&C past experience.
	Copes-Vulcan	D-100	6"diam x 17"h to 29"diam x 72"h				
	Hills-McCanna*	Ramcon R35B Ramcon R35BFS					
	Fisher	656 657 470					
	Masoneilan	37 71					
4. Thermocouple	Thermo Electric	Type E & K	5"w x 5"d x L (L = insertion length +5" for head. Maximum insertion length may be assumed to be 12".)	6	$500	$3,000	
	PYCO	Type E & K					
	RDF*	Type E & K					
	Leeds & Northrup	Type E & K					

CLASS 1E EQUIPMENT TABLE
(Continued)

EQUIPMENT	MANUFACTURER	MODEL NUMBER	PHYSICAL SIZE**	NUMBER OF TEST SPECIMEN REQUIRED	ESTIMATED COST UNIT	ESTIMATED COST TOTAL	REMARKS
5. RTD	Thermo Electric	RTD - 100 Ω Platinum	5"w x 5"d x L (L = insertion length +5" for head. Maximum insertion length may be assumed to be 12".)	4	$2,000	$8,000	
	Rosemount	RTD - 100 Ω Platinum					
	PYCO	RTD - 100 Ω Platinum					
	RDF*	RTD - 100 Ω Platinum					
	Leeds & Northrup	RTD - 100 Ω Platinum					
6. Limit Switch	NAMCO	EA 740 EA 180	7"h x 3"w x 4"d	4	$200	$800	
	Micro Switch	Series ML Series LS					
7. Differential Pressure Switch	Barton	583-197 583-224 583-199	14"h x 8"w x 12"d	6	$1,500	$9,000	
	Mercoid	Series C Series DP Series BB	7"diam x 5"d 7"h x 6"w x 4"d				
	Merium*	Series 1220					
	Static-O-Ring*	18R3	9"h x 4"w x 4"d				
8. Pressure Switch	Mercoid*	D-7040 D-7030 Series A	6"diam x 4"d 4"h x 6"w x 3"d	5	$300	$1,500	No manufacturer has 1E qualified equipment. The estimated cost includes an allowance proportioned to the price based on past UE&C experience.
	Static-O-Ring	12NN	6"h x 4"w x 4"d				
	Barksdale*	D2T B2T	5"h x 4"w x 5"d 7"h x 5"w x 3"d				
	ASCO	SB11	8"h x 4"w x 4"d				
	United Electric	H302-550 H302-126	6"h x 5"w x 5"d				

CLASS 1E EQUIPMENT TABLE
(Continued)

EQUIPMENT	MANUFACTURER	MODEL NUMBER	PHYSICAL SIZE**	NUMBER OF TEST SPECIMEN REQUIRED	ESTIMATED COST UNIT	ESTIMATED COST TOTAL	REMARKS
9. Solenoid Valves	ASCO	NP8316 NP8323 NP8344	9"h x 5"w x 5"d	5	$1,200	$6,000	
	Valcor	V70900					
	Atkomatic*	Series 30000 Series 15000					
	Marotta*	M22 M32					
	Target Rock	SM	16"h x 16"w x 5"d				
10. Terminal Blocks	General Electric	EB-25	3"w x 2"h x 4"L to 3"w x 2"h x 34"L L = dependent on # of poles	5	2Poles $6.00 to 24Poles $40.00	$30.00 to $200.00	Length and prices of terminal block dependent on number of poles. Data has been given for 2 pole and 24 pole terminal blocks.
	Multi-Amp	ZMW NT					
	Westinghouse	3710A95G04 TBA100					
	Buchanan*						
11. Enclosure	Hoffman	NEMA 12	12"h x 24"w x 6"d to 72"h x 30"w x 24"d	1	$200 to $800	$200 to $800	Due to the fact that enclosures are not electric (therefore not 1E) the estimated cost includes an allowance proportional to the price based on past UE&C experience. Price is dependent on size of enclosure and prices given are for the two sizes listed.
12. Radiation Monitoring System (AREA)	Nuclear Measurement Corp.	GA-2TO	15"h x 12"w x 9"d	3	$ 2,500	$ 7,500	
	Victoreen	855	detector-3" diam x 7"h Module- 5"h x 7"w x 12"d				
	General Atomic	RAC-1	detector-5" diam x 7"h Module- 9"h x 3"w x 21"d				

CLASS 1E EQUIPMENT TABLE
(Continued)

EQUIPMENT	MANUFACTURER	MODEL NUMBER	PHYSICAL SIZE**	NUMBER OF TEST SPECIMEN REQUIRED	ESTIMATED COST UNIT	ESTIMATED COST TOTAL	REMARKS
13. Radiation Monitoring System (Airborne-Particulate, Gaseous, Iodine)	Nuclear Measurement Corporation	AM-331F	39"h x 50"w x 21"d				
	Victoreen	840-1	54"h x 28"w x 33"d	5	$50,000	$250,000	This equipment is located outside containment but has been considered in this listing because of the potential for extremes of environmental conditions due to a high energy pipe rupture.
	General Atomic	RD-36 RD-35 RD-32	22"h x 14"w x 17"d 22"h x 11"w x 11"d 32"h x 11"w x 11"d				
14. Hydrogen Analyzer	Delphi	B	12"h x 11"w x 7"d				
	International Sensor Technology	AG3100	6"h x 3"w x 10"d	3	$8,000	$24,000	This equipment is located outside containment but has been considered in this listing because of the potential for extremes of environmental conditions due to a high energy pipe rupture.
	MSA*	802	12"h x 19"w x 12"d				
	Bacharach	CD 850					
15. Terminal Lugs	Burndy	Type YAEV Type YA-N	3"L x 1"w x 1"h to 9"L x 3"w x 1"h	1 1	$20/1000 $400/100	$20/1000 $400/100	Due to the difference in the three listed models of terminal lugs, the estimated cost of each model is listed.
	AMP	No. 10 AWG, crimped full-ring type, insulated gripping sleeve type, nuclear pre-insulated diamond grip, PVF_2 insulation	3"L x 1"w x 1"h to 9"L x 3"w x 1"h	1	$200/1000	$200/1000	

CLASS 1E EQUIPMENT TABLE
(Continued)

EQUIPMENT	MANUFACTURER	MODEL NUMBER	PHYSICAL SIZE**	NUMBER OF TEST SPECIMEN REQUIRED	ESTIMATED COST UNIT	ESTIMATED COST TOTAL	REMARKS
16. 300V Instrument Cable	Okonite	Single insulated copper conductor twisted in shielded pairs with drain wire cabled in single or multiple pairs					
	Anaconda	Single insulated copper conductor twisted in shielded pairs with drain wire cabled in single or multiple pairs					
	ITT	Single insulated copper conductor twisted in shielded pairs with drain wire cabled in single or multiple pairs	1" diam. x length	4	$200/1000FT	$800/1000FT	
	General Electric	Single insulated copper conductor twisted in shielded pairs with drain wire cable in single or multiple pairs					
17. 300V Thermocouple Cable	Okonite	Solid wire, twisted and shielded with copper drain wire. Type EX and KX					
	Anaconda	Solid wire, twisted and shielded with copper drain wire. Type EX and KX					
	General Electric	Solid wire, twisted and shielded with copper drain wire. Type EX and KX	1" diam. x length	4	$200/1000FT	$800/1000FT	
	ITT	Solid wire, twisted and shielded with copper drain wire. Type EX and KX					

CLASS 1E EQUIPMENT TABLE
(Continued)

EQUIPMENT	MANUFACTURER	MODEL NUMBER	PHYSICAL SIZE**	NUMBER OF TEST SPECIMEN REQUIRED	ESTIMATED COST UNIT	ESTIMATED COST TOTAL	REMARKS
18. 600V Control Cable	Okonite	2/c #14 multi-conductor copper cable	1" diam. x length	4	$200/1000FT	$800/1000FT	
	Anaconda	2/c #14 multi-conductor copper cable					
	General Electric	2/c #14 multi-conductor copper cable					
	ITT*	2/c #14 multi-conductor copper cable					
19a. 5 KV Cable	Anaconda	4/0 3 conductors cabled together with interlocked armor and overall jacket	2" diam. x length	4	$2000/1000FT	$ 8000/1000FT	This equipment is located outside containment but has been considered in this listing because of the potential for extremes of environmental conditions due to a high energy pipe rupture.
	General Electric	4/0 3 conductors cabled together with interlocked armor and overall jacket					
	Cyprus	4/0 3 conductors cabled together with interlocked armor and overall jacket					
	Okonite	4/0 3 conductors cabled together with interlocked armor and overall jacket					

CLASS 1E EQUIPMENT TABLE
(Continued)

EQUIPMENT	MANUFACTURER	MODEL NUMBER	PHYSICAL SIZE**	NUMBER OF TEST SPECIMEN REQUIRED	ESTIMATED COST UNIT	ESTIMATED COST TOTAL	REMARKS
19b. 5 KV Cable	Anaconda	350 MCM 3 conductors triplexed together without interlocked armor and overall jacket	3" diam. x length	4	$8000/1000FT	$32000/1000FT	This equipment is located outside containment but has been considered in this listing because of the potential for extremes of environmental conditions due to a high energy pipe rupture.
	General Electric	350 MCM 3 conductors triplexed together without interlocked armor and overall jacket					
	Cyprus	350 MCM 3 conductors triplexed together without interlocked armor and overall jacket					
	Okonite	350 MCM 3 conductors triplexed together without interlocked armor and overall jacket					
20. Motor	Siemens-Allis	125-250 HP, 460V 300-3500 HP, 4KV	23"h x 24"w x 15"d to 50"h x 64"w x 33"d	9	$5,000 to $15,000	$45,000 to $135,000	
	Reliance	0-100 HP, 460V					
	Westinghouse	0-100 HP, 460V 125-250 HP, 460V 300-3500 HP, 4KV					
	General Electric	0-100 HP, 460V 125-250 HP, 460V 300-3500 HP, 4KV					

CLASS 1E EQUIPMENT TABLE
(Continued)

EQUIPMENT	MANUFACTURER	MODEL NUMBER	PHYSICAL SIZE**	NUMBER OF TEST SPECIMEN REQUIRED	ESTIMATED COST UNIT	ESTIMATED COST TOTAL	REMARKS
21a. Penetrations - Power	Westinghouse Amphenol Conax D. C. O'Brien	Low Voltage Power 600V 750 MCM	2" diam. x 72" L	4	$15,000	$60,000	
21b. Penetrations - Control	Westinghouse Amphenol Conax D. G. O'Brien	Low Voltage Control - 600V #10	2" diam. x 72"L	4	$60,000	$ 240,000	
21c. Penetrations - Instrumentation	Westinghouse Amphenol Conax D. G. O'Brien	Instrument - 300 V #16 AWG	2" diam. x 72"L	4	$ 60,000	$ 240,000	
22a. 600V Power Cable	Cyprus* Rockbestos Okonite General Electric Anaconda	3/c #12 Jacketed cable	1" diam x Length	4	$400/1000FT	$1600/1000FT	
22b. 600V Power Cable	Cyprus* Rockbestos Okonite General Electric Anaconda	250 MCM 3 Conductor Triplexed	3" diam. x Length	4	$4000/1000FT	$16000/1000FT	

CLASS 1E EQUIPMENT TABLE
(Continued)

EQUIPMENT	MANUFACTURER	MODEL NUMBER	PHYSICAL SIZE**	NUMBER OF TEST SPECIMEN REQUIRED	ESTIMATED COST UNIT	TOTAL	REMARKS
23. Connectors	Amphenol	Triax					
	ITT Cannon	4/c #10 crimp & 5/c #1/0 Pressure					
	Bendix	4/c #10 crimp & 5/c #1/0 Pressure					
	Anaconda	4/c #10 crimp & 5/c #1/0 Pressure	1" diam. x 4"L	6	$300	$1800	
	Conax	4/c #10 crimp & 5/c #1/0 Pressure					
	Plye National	4/c #10 crimp & 5/c #1/0 Pressure					
24. Switchboard Wire	General Electric	SIS 1/c #14	1" diam. x Length	1	$61/1000FT	$61/1000FT	
25. Rotometers	Schulte & Koerting	S	12"h x 10"w x 7"d	2	$ 7,500	$ 15,000	No manufacturer has 1E qualified equipment. The estimated cost includes an allowance proportional to the price based on past UE&C experience.
	Brooks Instrument Company	5520A					
26. Neutron Monitors Out-Of-Core	General Electric		7" diam. x 133"Length	4	$ 15,000	$ 60,000	
	Westinghouse						
	General Atomic	NLW-2					
	Reuter Stokes						
27. Level Switch	Magnetrol	A103 291	10" diam x 24"h 10" diam x 24"h	4	$ 900	$ 3,600	
	Mercoid	201 401	7" diam x 19"h 7" diam x 25"h				

CLASS 1E EQUIPMENT TABLE
(Continued)

EQUIPMENT	MANUFACTURER	MODEL NUMBER	PHYSICAL SIZE**	NUMBER OF TEST SPECIMEN REQUIRED	ESTIMATED COST UNIT	ESTIMATED COST TOTAL	REMARKS
28. Splices	Raychem	WCSF-N Series	½" - 2" Diameter by 6" - 24" Long	5	$50	$250	

* Manufacturer not included in number of test specimen required.
** Height x Width x Depth

APPENDIX B

Alternative 1,
Dedicated Test Facility,
FRC Report F-C4781-2

STUDY OF RESOURCES AND COSTS TO ESTABLISH A LABORATORY DEDICATED TO QUALIFICATION VERIFICATION TESTING OF CLASS 1 SAFETY-SYSTEM EQUIPMENT

FRC Final Report
F-C4781-2

Prepared by

L. G. Haskins
S. P. Carfagno

Prepared for

SANDIA LABORATORIES
ALBUQUERQUE, NEW MEXICO

Final Draft — April 1979
Final Report — July 1979

(Contract No. 07-3462, Mod. No. 5)

Franklin Research Center
A Division of the Franklin Institute
The Benjamin Franklin Parkway
Philadelphia, PA 19103

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FIGURES

TABLES

TABLES (cont.)

SUMMARY

This study was conducted to estimate the resource requirements and costs involved in the design, construction, equipping, staffing, and operation of a laboratory facility dedicated to performing environmental qualification verification tests in accordance with IEEE Std 323-1974* and other applicable standards for reactor safety-system equipment used in nuclear power generating systems. It was conducted by Franklin Research Center (FRC) under contract to Sandia Laboratories.

The list of Class 1 safety-system equipment addressed in this study, which includes 135 specimens in 28 categories, was prepared by United Engineers & Constructors, Inc. General guidelines for the laboratory and its capabilities were supplied to FRC by Sandia Laboratories and the Nuclear Regulatory Commission.

The proposed laboratory will be capable of performing the following tests: accelerated aging (thermal, vibrational and operational), gamma irradiation (normal and accident conditions), and simulation of a high-energy-line-break (HELB). Provisions were also made for possible future expansion of the scope of the laboratory to include research on aging of materials and the development and/or verification of qualification testing techniques. Therefore, the design of the facility and space allocation provide for potential future expansion of the staff and acquisition of additional laboratory equipment.

The design, cost, staffing and operating schedule of the laboratory were determined for each of two different operating modes, identified as Phase I and Phase II. In Phase I it was intended that the test specimens be processed essentially one at a time, in a *sequential* mode. This mode of operation economizes on the testing facilities, but extends the time required to complete all of the tests. Accordingly, a *parallel* mode of operation was considered in Phase II, with the testing facilities expanded to accommodate several test specimens simultaneously, so that the entire backlog of specimens could be processed in significantly less time than that required in the sequential mode of Phase I.

Because of the wide variation in the size of the test specimens, it was decided that two HELB test vessels, a small one in addition to one large enough to accommodate the largest specimen, should be provided in

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*IEEE Std 323-1974, "IEEE Standard for Qualifying Class IE Equipment for Nuclear Power Generating Stations," The Institute of Electrical and Electronics Engineers, Inc., New York, NY, 1974.

Phase I. Sufficient ancillary equipment was included to keep the larger chamber (in which most of the specimens will be tested) operating without holdup. With the laboratory so equipped, it was found that four years would be required to process the entire backlog of 135 test specimens.

The criterion chosen for Phase II of the study was that the laboratory be equipped and staffed so that all of the test specimens could be processed in one and one-half years, i.e., less than half the processing time required in the mode of operation of Phase I.

The time required to plan, design and build the laboratory, to equip it with laboratory, office and support facilities, and to staff the organization and put it into operation was estimated as 4.5 years for either mode of operation.

A staff of 128 professional and administrative personnel is suggested to sustain operations in the sequential mode and 245 in the parallel mode. The estimate of overall costs and schedule for the two modes of operation are given in the following table:

	PHASE I SEQUENTIAL MODE		PHASE II PARALLEL MODE	
	Time (Years)	Cost (Thousands)	Time (Years)	Cost (Thousands)
STARTUP				
Construction of laboratory and initial checkout of facilities	4.5	10,900	4.5	19,752
TESTING				
Backlog of 135 specimens	4.0	22,200	1.5	12,962
FOLLOW-ON				
Research initiated, testing effort reduced	1.5	10,400	2.0	20,325
TOTAL	10.0	43,500	8.0	53,039

All equipment costs were based on 1978 prices; labor costs were based on 1978 rates for the first year, with an annual escalation rate of ten percent. The cost of land and the installation of electric power, water supply and sewer services were not included.

It was decided at the outset that the purpose of this study could be achieved by basing cost estimates largely on prior experience, and the time and funding limitations imposed on the study were consistent with this premise. Some supporting data for cost estimates were obtained through communication with potential suppliers of equipment and services; but this was the exception rather than the rule. Therefore, the accuracy of data supplied herein may be within ±50% of actual costs, which was considered adequate for the purpose of evaluating the concept of an independent verification laboratory against alternative concepts.

Before the design and construction of the laboratory can be initiated, in-depth cost analyses must be conducted to identify resource requirements and costs more accurately than was possible in this study. It is cautioned that peripheral studies such as building safety analyses, environmental impact studies and OSHA requirements were not included in this study.

Acknowledgements are hereby given to everyone whose invaluable contributions assisted FRC in conducting the study. As noted above, United Engineers & Constructors, Inc., supplied the list of Class 1 safety-system equipment used in this study. The assistance of several members of the Sandia Laboratories and the Nuclear Regulatory Commission staffs, who provided general guidelines for the study, is gratefully acknowledged. Mr. I. John Niemkiewicz, a Principal Engineer at FRC, helped generate the first draft of this report.

1. INTRODUCTION

1.1 OBJECTIVE

The objective of the study documented in this report was to estimate the costs involved in designing, constructing, equipping, staffing, and operating a test facility which could be used for conducting environmental tests, in accordance with IEEE Std 323-1974 and other applicable standards and Regulatory Guides, on environmentally-sensitive equipment.

1.2 SCOPE OF THE STUDY

Guidelines for the study specified that:

> "The analysis shall address environmentally-sensitive safety-related equipment that is located in areas potentially exposed to a harsh environment and that is required to function during or following a design basis event for safe plant shutdown or otherwise required to mitigate the consequences of an accident. By definition..., the analysis will consider safety-significant electrical, instrumentation and control, and electro-mechanical equipment.
>
> "The analysis shall address equipment currently being supplied and installed in plants under construction and such equipment approved for use in the future."

It was further stipulated that:

> "An acceptable test scope for each equipment category will be defined using current standards such as IEEE Std 323-1974 and considering current state-of-the-art for such technical areas as accelerated aging practices."

It was specified that:

> "... [the] test facility [be] capable of conducting the environmental tests in accordance with standards such as IEEE Std 323-1974."

In a clarification of this requirement, seismic testing was explicitly excluded.

The design, staffing and cost of the facility were to be analyzed in accordance with two different operating modes:

In Phase I it was to be assumed that one test chamber would be provided for simulating high-energy-line-break (HELB) conditions, and that sufficient support equipment would be provided to keep the HELB test chamber in continuous operation. In other words, the Phase I analysis was based on a *sequential* mode of operation, in which the safety-system-equipment specimens would be processed essentially one at a time. As will be discussed in Section 9, it was decided during the course of the study that Phase I should be based on the provision of two HELB test chambers, a *large* one and a *small* one, because of the wide variation in test specimen size. A consequence of the Phase I mode of operation was that the time required to process the entire backlog of safety-system equipment (exclusive of the time to build the facility and put it into operation) was found to be four years.

In Phase II it was assumed that sufficient HELB test chambers and supporting facilities would be provided to permit the processing of all safety-system-equipment specimens in a calendar period of one and one-half years, i.e., less than half the time required in the Phase I mode. This was termed the *parallel* mode of operation, since several specimens would be advancing through the testing process (in parallel) at any one time.

The definition of the Phase I study (which is also applicable to the Phase II analysis) further stipulated that:

1. "The test chamber shall be sized to accommodate the largest component assembly known that could potentially be subjected to the harsh environment caused by a LOCA or other high-energy-line-break including those outside containment.

2. "The facility equipment shall be capable of simulating ... environmental conditions including ... non-seismic vibration of PWR and BWR nuclear power plants under the most severe accident conditions.

3. "The facility equipment shall be capable of simulating radiation and thermal aging of component assemblies.

4. "The facility equipment shall be capable of monitoring component performance in the energized state.

5. "The facility shall be equipped to do long-term aging studies.

6. "Storage space shall be considered in the facility size study."

The analysis of the resource requirements and resultant costs for Phase I is presented in Sections 2 through 12 of this report; the effects of the Phase II mode on projected costs and schedule of operation are discussed in Section 13.

2. EQUIPMENT TO BE TESTED

Table 2-1 identifies the specific equipment to be tested.* The main criterion for inclusion in this list was that the equipment be susceptible to exposure to the harsh environmental conditions associated with a high-energy-line-break (HELB). Thus the equipment is not strictly limited to that located inside the containment of a nuclear power generating station; it includes some equipment located in areas outside the containment but nonetheless susceptible to an HELB (this equipment is indicated by the symbol "¶" in Table 2-1). Practically all of the items listed in Table 2-1 are Class 1E, i.e., safety-system electrical equipment (see IEEE Std-323 1974); categories 3 and 11 (indicated by "Not 1E" in Table 2-1) include the only non-electrical items. The list includes 135 items in 28 categories. While this list is not all-inclusive, it was estimated by UE&C to include 90 to 95 percent of the equipment in the Class 1E category.

In addition to manufacturer, model number and size data, Table 2-1 indicates:

- the number of different models in each equipment category;
- whether or not equipment in one category can be tested with equipment in another category;
- which test vessel will be used for the HELB simulation; and
- how many specimens will be tested together.

Further discussion of these data will be found in subsequent sections of this report.

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*Information reported in the first four columns was provided in a tabulation prepared by United Engineers & Constructors, Inc., (UE&C) for Sandia Laboratories.

Table 2-1. Identification of Safety-System Equipment

Equipment	Manufacturer	Model Number	Approximate Overall Dimensions*	Maximum Volume (ft^3)	Number of Test Specimens	Test Combined With Other Specimens?	Test in 3-ft-diam by 4-ft-high Vessel	Test in 6-ft-diam by 10-ft-high Vessel	Remarks
1. Transmitters (Primarily Pressure)	Barton Rosemount Westinghouse Foxboro	763 764 1153DP 1153HP 1153AP 1153GP Veritrak 76 E11GM E11AM E11DM E13DM	5' x 5" x 8" 9" x 5" x 5" 5" x 5" x 8" 14" x 7" x 7"	1	11	No	—	Test all eleven as a group	
2. Actuators (Electric)	Limitorque Rotork	Series SB Series SBD Series SMB NA1 NA2	14" x 41" x 21" to 22" x 41" x 21"	11	5	No	One at a time; five times	—	Depending upon actual size, it may be practical to test two specimens at a time.
3. Actuators (Pneumatic) (Not 1E)	Matryx Copes-Vulcan Hills-McCanna† Fisher Masoneilan	26072-SR60 D-100 Ramcon R35B Ramcon R35BFS 656 657 470 37 71	11" x 60" x 8" 6" diam x 17" h to 29" diam x 72" h	28	7	No	—	Two at a time; four times	Size may influence number of items per test.
4. Thermocouple	Thermo Electric PYCO RDF† Leeds & Northrup	Type E & K Type E & K Type E & K Type E & K	5" w x 5" d x L$^{\Delta}$	0.2	6	Yes	Test all six as a group with item 5	—	
5. RTD (Resistance Temperature Device)	Thermo Electric Rosemount PYCO RDF† Leeds & Northrup	RTD - 100Ω Platinum RTD - 100Ω Platinum RTD - 100Ω Platinum RTD - 100Ω Platinum RTD - 100Ω Platinum	5" w x 5" d x L$^{\Delta}$	0.2	4	Yes	Test all four as a group with item 4		
6. Limit Switch	NAMCO Micro Switch	EA740 EA180 Series ML Series LS	7" x 3" x 4"	0.1	4	Yes	Test all four as a group with items 7 and 8	—	

Table 2-1. Identification of Safety-System Equipment (cont.)

Equipment	Manufacturer	Model Number	Approximate Overall Dimensions*	Maximum Volume (ft^3)	Number of Test Specimens	Test Combined With Other Specimens?	Test in 3-ft-diam by 4-ft-high Vessel	Test in 6-ft-diam by 10-ft-high Vessel	Remarks
7. Differential Pressure Switch	Barton	583-197 583-224 583-199	14" x 8" x 12"	0.8	6	Yes	Test all six as a group with items 6 and 8	—	Actual sizes may influence number of specimens per test.
	Mercoid	Series C Series DP Series BB	7" diam x 5" d 7" x 6" x 4"						
	Merium†	Series 1220							
	Static-O-Ring†	18R3	9" x 4" x 4"						
8. Pressure Switch	Mercoid†	D-7040 D-7030 Series A	6" diam x 4" d 4" x 6" x 3"	0.1	4	Yes	Test all four as a group with items 6 and 7	—	Actual sizes may influence number of specimens per test.
	Static-O-Ring	12NN	6" x 4" x 4"						
	Barksdale†	D2T B2T	5" x 4" x 5" 7" x 5" x 3"						
	ASCO	SB11	8" x 4" x 4"						
	United Electric	H302-550 H302-126	6" x 5" x 5"						
9. Solenoid Valves	ASCO	NP8316 NP8323 NP8344	9" x 5" x 5"	0.2	5	No (see remarks)	Test all five as a group	—	It may be practical to combine some solenoid valves with tests of items 6, 7 and 8 above.
	Valcor	V70900							
	Atkomatic†	Series 30000 Series 15000							
	Marotta†	Series M22 Series M32							
	Target Rock	SM							
10. Terminal Blocks	General Electric	EB-25	3" x 2" h x 4" L to 3" w x 2" h x 34" L (L is dependent on no. of poles)	0.2	5	Yes	Put blocks inside enclosure and test all five as a group	—	The arrangement and orientation of blocks within the enclosure and penetrations to the enclosure may be important. More than one enclosure may be recommended, but test all in one vessel (see items 11 and 15).
	Multi-Amp	NT ZMW							
	Westinghouse	3710A95G04 TBA100							
	Buchanan†								

Table 2-1. Identification of Safety-System Equipment (cont.)

Equipment	Manufacturer	Model Number	Approximate Overall Dimensions*	Maximum Volume (ft^3)	Number of Test Specimens	Test Combined With Other Specimens?	Test in 3-ft-diam by 4-ft-high Vessel	Test in 6-ft-diam by 10-ft-high Vessel	Remarks
11. Enclosure	Hoffman	NEMA 12	12" x 24" x 6" to 72" x 30" x 24"	1 to 30	1	Yes	Test with terminal blocks	—	
12. Radiation Monitoring System (Area)	Nuclear Measurement Corp.	GA-2TO	15" x 12" x 9"	1	3	No	—	Test all three as a group	A portable gamma source may be recommended for functional tests of sensors within the test vessel.
	Victoreen	855	Detector: 3" diam x 7" h Module: 5" x 7" x 12"						
	General Atomic	RAC-1	Detector: 5" diam x 7" h Module: 9" x 3" x 21"						
13. Radiation Monitoring System[¶] (Airborne - Particulate, Gaseous Iodine)	Nuclear Measurement Corp.	AM-331F	39" x 50" x 21"	1	5	No	—	Test all five as a group	
	Victoreen	840-1	54" x 28" x 33"						
	General Atomic	RD-36 RD-35 RD-32	22" x 14" x 17" 22" x 11" x 11"						
14. Hydrogen Analyzer[§]	Delphi	8	12" x 11" x 7"	1.6	3	No	—	Test all three as a group	
	International Sensor Technology	AG3100	6" x 3" x 10"						
	MSA[†]	802	12" x 19" x 12"						
	Bacharach	CD850							
15. Terminal Lugs	Burndy	Type YAEV Type YA-N	3" L x 1" w x 1" h to 9" L x 3" w x 1" h	0.1	3	Yes	Test all three as a group	—	Combine with terminal blocks and enclosures.
	AMP	#10 AWG, crimped full-ring type, insulated gripping sleeve type, nuclear pre-insulated diamond grip, PVF_2 insulation							

Table 2-1. Identification of Safety-System Equipment (cont.)

Equipment	Manufacturer	Model Number	Approximate Overall Dimensions*	Maximum Volume (ft^3)	Number of Test Specimens	Test Combined With Other Specimens?	Test in 3-ft-diam by 4-ft-high Vessel	Test in 6-ft-diam by 10-ft-high Vessel	Remarks
16. 300-V Instrument Cable	Okonite Anaconda ITT General Electric	Approx. #18 AWG single insulated copper conductor twisted in shielded pairs with drain wire cables in single or multiple pairs	1" diam x 30' L	▽	4	Test with items 17 and 18	Test all four as a group	—	The number of cables to be tested at one time in a vessel should not exceed 15 cables and 60 conductors.
17. 300-V Thermocouple Cable	Okonite Anaconda ITT General Electric	Approx. #20 AWG solid wire, twisted and shielded with copper drain wire. Type EX and KX.	1" diam x 30' L	▽	4	Test with items 16 and 18	Test all four as a group	—	
18. 600-V Control Cable	Okonite Anaconda ITT[†] General Electric	2/C #14 AWG multiconductor copper cable	1" diam x 30' L	▽	3	Test with items 16 and 17	Test all three as a group	—	
19a. 5-kV Cable[¶]	Anaconda General Electric Cyprus Okonite	#4/0 three-conductor cables together with inter-locked armor and overall jacket	2" diam x 30' L	▽	4	Test with item 19b	Test all four as a group	—	
19b. 5-kV Cable[¶]	Anaconda General Electric Cyprus Okonite	350 MCM three-conductor triplexed together without armor and overall jacket	3" diam x 30' L	▽	4	Test with item 19a	Test all four as a group	—	

Table 2-1. Identification of Safety-System Equipment (cont.)

Equipment	Manufacturer	Model Number	Approximate Overall Dimensions*	Maximum Volume (ft³)	Number of Test Specimens	Test Combined With Other Specimens?	Test in 3-ft-diam by 4-ft-high Vessel	Test in 6-ft-diam by 10-ft-diam Vessel	Remarks
20. Motor	Siemens-Allis	125-250 hp, 460 V 300-3500 hp, 4 kV	3' diam x 6' h	43	6	No	—	One at a time; six times	a) motors > 400 hp will be analyzed using field data, subassemblies or critical components only. b) a motor loading d ice (e.g., water brake) may be required.
	Reliance	0-100 hp, 460 V							
	Westinghouse	0-100 hp, 460 V 125-250 hp, 460 V 300-3500 hp, 4 kV							
	General Electric	0-100 hp, 460 V 125-250 hp, 460 V 300-3500 hp, 4 kV							
21a. Penetrations - Power	Westinghouse Amphenol Conax D. G. O'Brien	Low Voltage Power 600 V, 750 MCM	2" diam x 72" L	▽	4	No	—	One at a time; four times	Vessel modifications may be required to provide pressure/temperature differential across penetrations.
21b. Penetrations - Control	Westinghouse Amphenol Conax D. G. O'Brien	Low Voltage Control 600 V, #10 AWG	2" diam x 72" L	▽	4	No	—	One at a time; four times	
21c. Penetrations - Instrumentation	Westinghouse Amphenol Conax D. G. O'Brien	Instrument - 300 V, #16 AWG	2" diam x 72" L	▽	4	No	—	One at a time; four times	
22a. 600-V Power Cable	Cyprus† Rockbestos Okonite General Electric Anaconda	3/C #12 AWG jacketed cable	1" diam x 30' L	▽	4	Yes	Test all four as a group with items 23 and 24	—	The number of cables to be tested at one time in a vessel should not exceed 15 cables and 60 conductors.
22b. 600-V Power Cable	Cyprus† Rockbestos Okonite General Electric Anaconda	250 MCM three-conductor triplexed	3" diam x 30' L	▽	4	Yes	Test all four as a group with items 23 and 24	—	

Table 2-1. Identification of Safety-System Equipment (cont.)

Equipment	Manufacturer	Model Number	Approximate Overall Dimensions*	Maximum Volume (ft^3)	Number of Test Specimens	Test Combined With Other Specimens?	Test in 3-ft-diam by 4-ft-high Vessel	Test in 6-ft-diam by 10-ft-high Vessel	Remarks
23. Connectors	Amphenol ITT Cannon Bendix Anaconda Conax Pyle-National	Triax 4/C #10 crimp & 5/C #1/0 pressure	1" diam x 4" L	0.002	6	Yes	Test all six as a group with items 22a, 22b and 24	—	It may be desirable to include items 23 and 24 with items 16, 17, 18 and 22 for schedule efficiency
24. Switchboard Wire	General Electric	SIS 1/C #14 AWG	1" diam x 30' L	∇	1	Yes	Test with items 22a, 22b and 23	—	
25. Rotometers	Schulte & Koerting Brooks Instrument Co.	S 5520A	12" x 10" x 7"	0.5	2	No	Test both as a group	—	
26. Neutron Monitors Out-of-Core	General Electric Westinghouse General Atomic Reuter Stokes	NLW-2	7" diam x 133" L	3	4	No	—	Test all four as a group	May need portable neutron source to test performance during HELB.
27. Level Switch	Magnetrol Mercoid	A103 291 201 401	10" diam x 24" h 7" diam x 19" h 7" diam x 25" h	2	4	No	Test all four as a group	—	
28. Splices	Okonite				1	Yes	Test with cables	—	

Table 2-1. Identification of Safety-System Equipment (cont.)

Notes: *Unless otherwise indicated, the dimensions given are height x width x depth.

†Manufacturer model not to be tested (can be qualified by generic type).

$^{\Delta}$L = insertion length plus 5 in for head; maximum insertion length may be assumed to be 12 in.

¶Equipment located outside containment, but susceptible to harsh environments resulting from high-energy-line-breaks.

$^{\nabla}$Nominal cable volume is not representative of the volume the cable would occupy during testing inside the pressure vessel; cables are usually wrapped around a mandrel for testing purposes.

3. QUALIFICATION TEST PROGRAM

3.1 GENERAL PROGRAM DEFINITION

The requirements for qualification of safety-system equipment by testing include:

- accelerated aging of the specimen to simulate the maximum functional degradation that can take place prior to the occurrence of an accident that requires the equipment to perform a safety-related function;
- exposure of the aged specimen to simulated accident conditions to verify its functional capability during and following the accident.

Qualification testing programs, particularly accelerated aging procedures, must be tailored to the specific equipment being qualified; program elements may vary significantly among different categories of equipment. However, detailed analysis of different qualification programs was considered to be outside the scope of this study, which is based on a typical qualification program.

The elements of the typical qualification program assumed in this study are described in the following subsection.

3.2 DESCRIPTION OF TYPICAL QUALIFICATION PROGRAM

The elements of the typical qualification test program, consistent with the current status of equipment aging/qualification technology, are outlined in Table 3-1. Items 1 through 9 of Table 3-1 constitute simulation of equipment degradation combined with periodic functional testing; item 10 provides for the simulation of a high-energy-line-break (HELB). Each element is discussed separately in Sections 3.2.1 through 3.2.6.

Table 3-1. Elements of Typical Qualification Test Program

Test	Test Conditions	Required Test Time*	Section Reference
1. Initial inspection and baseline functional test	As specified by specimen design	variable	3.2.1
2. Accelerated thermal aging	Specimen placed in hot-air-circulating oven at temperature between 100° and 150°C	7 days	3.2.2
3. Intermediate functional test	See item 1		
4. Exposure to gamma radiation (aging and accident dose)	200 Mrad at a rate of approximately 0.5 Mrad/hour	20 days†	3.2.3
5. Intermediate functional test	See item 1		
6. Vibrational aging	Specimen subjected to low-level vibration at selected frequencies	2 days	3.2.4
7. Intermediate functional test	See item 1		
8. Operational aging	Specimen cycled through 2000 to 100,000 cycles or accelerated continuous operation, as appropriate	variable	3.2.5
9. Intermediate functional test	See item 1		
10. Accident (HELB) simulation	In accordance with profiles in Figure 3-1 or Figure 3-2	30 days	3.2.6
11. Final functional test and inspection	Measure characteristic parameter to evaluate effect of testing on functional capability of specimen. See item 1		

Notes: *Exclusive of test setup and setdown times.

†Assuming an average of 20 hours of radiation exposure per day.

The sequence of thermal aging, gamma irradiation, vibrational aging and operational cycling is typical of the test sequences used to simulate equipment aging in qualification programs. The adequacy of this sequence of tests in producing functional degradation equivalent to or exceeding that which occurs in service should be reviewed in the qualification of specific equipment. However, the typical sequence presented in Table 3-1 was considered adequate for the purposes of this study. Similarly, the test times listed in Table 3-1 are not firm, but representative values adequate for estimating the time required to complete a typical test program.

The simulation of equipment degradation caused by humidity in the normal service environment was omitted because qualification standards provide very little guidance on the acceleration of humidity effects, and for many items of safety-system equipment (particularly where the temperature in the immediate environment of the equipment, e.g., inside an enclosure, exceeds the ambient temperature), humidity effects under normal service conditions are considered negligible. Synergistic effects likewise have not been addressed; in part, because their simulation is beyond the present state of qualification technology, but also because most synergistic effects are considered second-order in comparison with the degradation caused by the sequence of tests listed in Table 3-1.

In estimating staff requirements, operating costs and time required to conduct the tasks of the laboratory, including development of acceptance criteria, it was assumed that the preparation of equipment aging/qualification plans was not within the scope of the laboratory's role and that qualification plans would be provided by others; however, one of the functions of the laboratory's staff will be to translate such qualification plans into test procedures. The staff will also be required to prepare test reports suitable for review by the Nuclear Regulatory Commission (NRC).

3.2.1 Baseline Functional Test

The safety equipment to be tested will be given an initial baseline functional test to ensure that the equipment performs within design specifications and has not been damaged in shipment or handling. The initial performance characteristics serve as a baseline for comparison with the performance after each element of the qualification program. By conducting functional tests before and after each test in the sequence, the effect of individual (aging) stresses on specimen performance can be monitored.

3.2.2 Accelerated Thermal Aging

The accelerated thermal aging of safety-system equipment requires an analysis of thermal degradation mechanisms under service conditions and the use of aging models to establish the temperature and duration of exposure to elevated thermal stress that will simulate the thermal degradation occurring in normal service over a period of real time. In this study, the duration of accelerated thermal aging was arbitrarily assumed to be 7 days. It was assumed that the equipment would be placed inside a hot-air-circulating oven and maintained at an elevated temperature (typically 100° to 150°C) for the 7-day period. As indicated in Section 3.2, it was assumed that the accelerated aging parameters would be specified to the laboratory.

3.2.3 Exposure to Gamma Radiation (Normal and Accident Conditions)

The gamma radiation exposure will combine the effect of normal service (radiation aging) and the simulation of irradiation due to a loss-of-coolant accident. The equipment will be subjected to a total dose of 200 Mrad of gamma radiation, based on the assumption that the radiation exposure integrated over 40 years of normal service for equipment inside the containment is 50 Mrad, and that the accident exposure integrated over one year is 150 Mrad. These doses are consistent with current practice for qualification of in-containment equipment. The irradiation will be conducted at an average dose rate of approximately 0.5 Mrad/h, although dose rates of up to 5.0 Mrad/h may be used at the start of the accident simulation. This yields a total exposure time of 400 hours. If we assume an effective exposure time of 20 hours per day to allow for interruptions of the exposure for activities such as performance monitoring or specimen re-orientation, the 400 hours converts to 20 days. It was assumed that irradiation would be conducted on a 7-day-per-week basis.

The equipment listed in Table 2-1 as being located outside the containment building may be qualified with a gamma radiation dose substantially smaller than 200 Mrad; however, this was ignored in the present analysis as it was not expected to have a major effect on the facility requirements and operating costs.

3.2.4 Vibrational Aging

Qualification standards and regulatory requirements do not generally provide specific guidance for simulating the effects of vibration in normal service—although this point is addressed, for example, in IEEE standards for the qualification of motors and valve actuators. For purposes of this study, it was decided that a reasonable estimate of facility and operating costs would be obtained by assuming that all equipment to be tested would be subjected to vibrational aging at selected frequences, at acceleration amplitudes not exceeding 5 g, for a total test duration (excluding setup and setdown) of 48 hours.

3.2.5 Operational Aging

It is current practice to simulate the functional deterioration caused by operating stresses other than heat by operating the test specimen continuously (e.g., motors) or cyclically (e.g., switches, relays and valve actuators), as appropriate. For continuously-operated equipment, the number of cycles used for operational aging varies with the equipment and its application; it ranges from approximately 2000 cycles (e.g., solenoid valves and electric valve actuators) to 10,000 or 100,000 cycles (e.g., relays and switches). For cyclically-operated equipment, accelerated operational aging procedures depend on the duty cycle and other factors pertinent to the equipment and its application.

3.2.6 Accident Simulation

In accordance with the scope discussed in Section 1, the only type of accident to be considered was a high-energy-line-break, which was interpreted as consisting of a loss-of-coolant accident (LOCA) or a steam-line-break (SLB) or a combination enveloping SLB and LOCA conditions. Simulation of LOCA/SLB conditions requires that the equipment specimen be placed inside a pressure vessel and exposed to steam and sprays of chemical solution or demineralized water. Typical temperature profiles for LOCA and SLB simulation are illustrated in Figures 3-1 and 3-2, respectively. It was assumed that the test duration would be 30 days, which is typical of many LOCA tests.

The exposure to gamma radiation that takes place during a LOCA or SLB was taken into account by combining the accident dose with the aging dose, as discussed in Section 3.2.3.

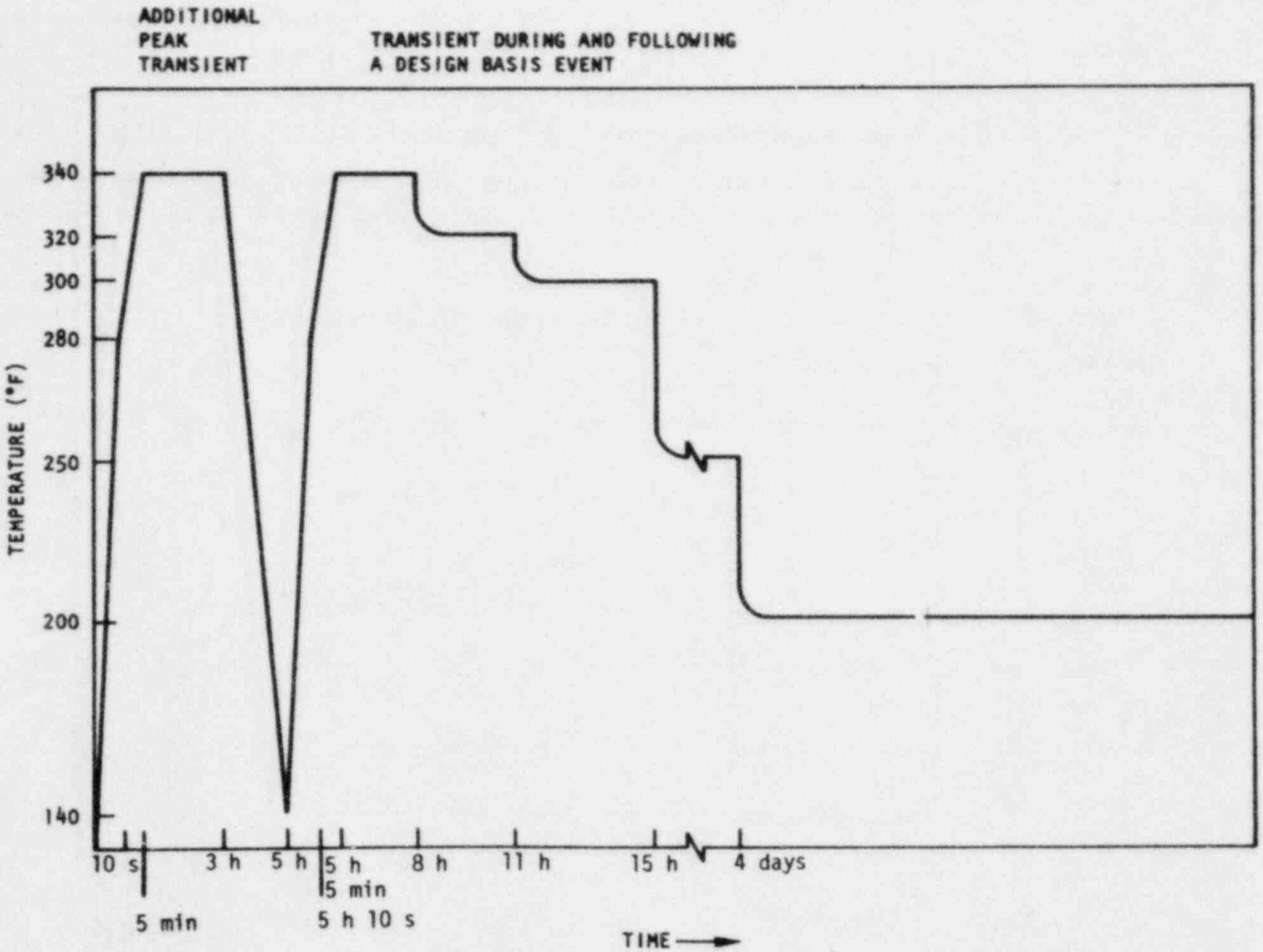
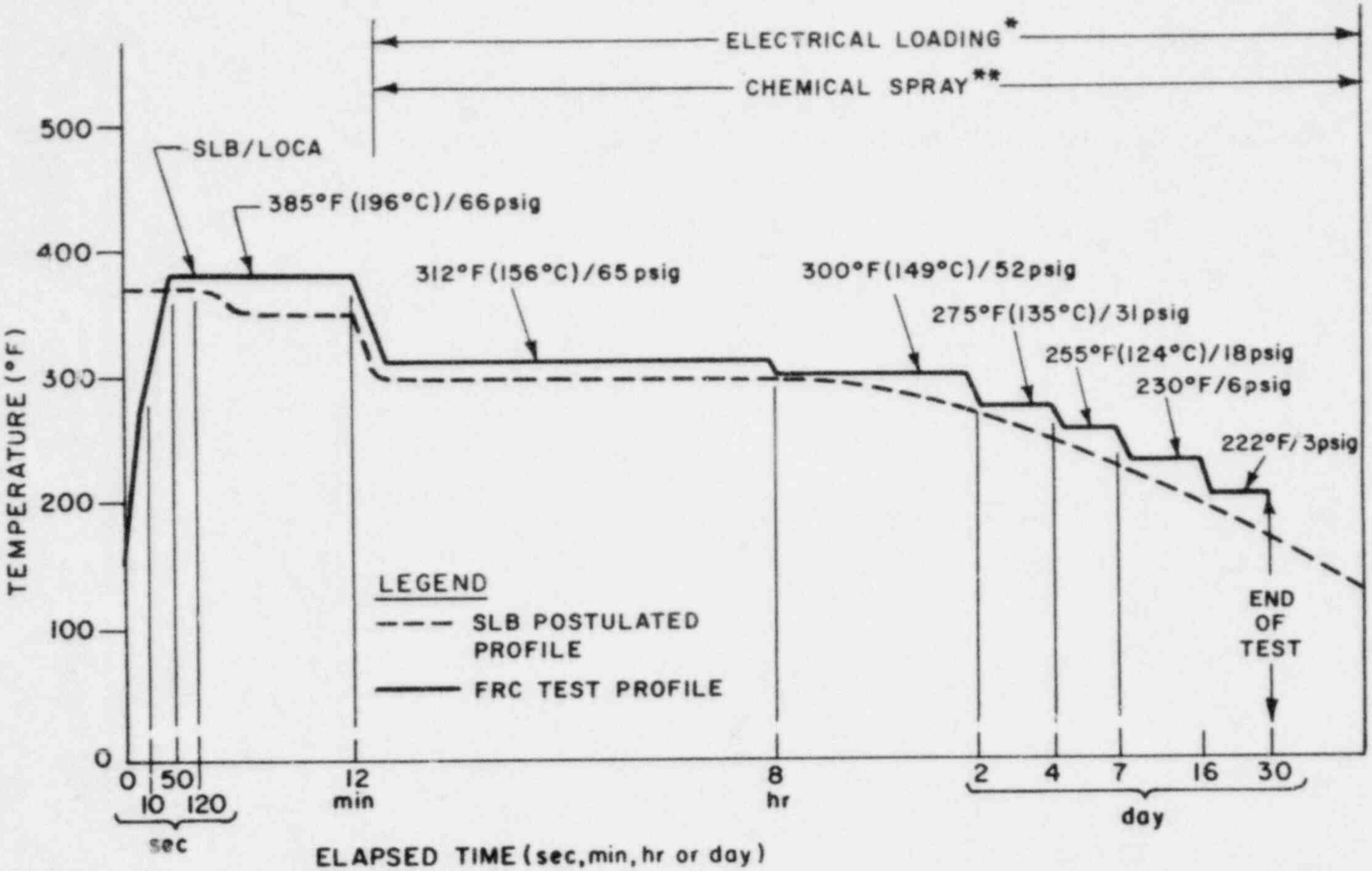


Figure 3-1. Temperature Profile for LOCA Simulation (Combined PWR/BWR)
(From IEEE Std 323-1974, Figure A1)



*Depending on specimens to be tested, electrical loading may be appropriate. If so, electrical loading may be interrupted for short periods to permit measurements.

**Continuous spray at a rate of at least 0.15 gallons per minute per square foot (6.1 liters per minute per square meter). The chemical solution is to be composed of:

6200 parts per million bcron as H_3BO_3
50 parts per million hydrazine (NH_2NH_2)
Na_3PO_4 and NAOH added to make the pH between 8.6 and 10.0 at 77°F in fresh solution storage tank.

Figure 3-2. Typical Temperature/Pressure Profile for a Simulated SLB/LOCA Steam/Chemical-Spray Exposure With Electrical Loading

4. TEST FACILITY REQUIREMENTS

4.1 GENERAL

The test facilities required to perform the qualification tests discussed in Section 3 are summarized in Table 4-1. Column 1 of this table shows equipment function and column 2 equipment necessary to conduct the test. Column 3 lists the floor space required for equipment installation, including work space, while column 4 lists approximate equipment cost. The general features of the equipment are discussed in subsequent paragraphs.

4.2 CIRCULATING-AIR OVENS

Specimens will be thermally aged in a circulating-air oven with a temperature range of 30° to 300°C. The oven will be designed for a maximum air flow rate of 250 feet per minute across the oven (to maintain constant temperature) and for an air exchange rate of one to one hundred times per minute. Two ovens will be sufficient to accommodate all test specimens. A small (3-ft by 3-ft by 4-ft-high interior) oven for aging small specimens and a larger (6-ft by 6-ft by 10-ft-high interior) oven for aging the largest specimen (i.e., a 400-hp motor) are recommended. Removable shelves and a heavy duty floor are required. Ancillary equipment include temperature recorders, an oven-temperature protection device, timers, and an elapsed time clock.

4.3 VIBRATION TABLES

Vibrational aging will be conducted on a vibration table capable of applying sinusoidal vibration at acceleration amplitudes of up to 5.0 g to the specimens. A small, 6-in-diam table will be utilized for small specimens; a larger, 6-ft-wide by 10-ft-long table will be needed for larger, heavier (>1000 lb) items.

Table 4-1. Test Facilities

FUNCTION	FACILITY	EST. FLOOR SPACE REQ'D (ft^2)	EST. COST (DOLLARS)
1. Thermal aging	• 3-ft by 3-ft by 4-ft-high oven	100	4,200
	• 6-ft by 6-ft by 10-ft-high oven	200	20,000
2. Vibrational aging	• 8-in-diam vibration table	50	500
	• 6-ft by 10-ft vibration table	100	10,000
	• Two exciter controls		24,500
3. Gamma irradiation	• Two hot cells	3,600	850,000
	• Six cobalt-60 sources		1,500,000
	• One 30-ton crane with 20-ft span	N/A	50,500 (installed)
4. HELB exposure	• 3-ft-diam by 4-ft-high pressure vessel	100	18,000
	• 6-ft-diam by 10-ft-high pressure vessel	200	36,000
	• 200-bhp steam generator	250	47,500
	• 200-kW steam superheater	100	90,000
5. Structural tests (force tests)	• Steel I-beams ("strong-back")	200	10,000
6. Electrical tests (functional tests, operational aging and cable electrical property tests)	• High-voltage power supply	100	N/A
	• Low-voltage power supply		N/A
	• Water immersion tank	500	5,000
	• Dielectric strength test set	100	15,000
	• Schering bridge	100	15,000
7. Test control and data acquisition center	• See Table 4-2	1,000	68,000
	• Computer (comparable to a CDC Cyber 171)	500	1,000,000
8. Special handling equipment	• One 10-ton crane with 20-ft span	N/A	29,000 (installed)
	• One 30-ton crane with 45-ft span	N/A	59,500 (installed)
		TOTAL	$3,852,700

The vibration tables will be mounted with isolation mountings onto a reinforced-concrete foundation to prevent the transmission of disturbing forces to the building or to adjacent equipment.

4.4 GAMMA IRRADIATION FACILITY

Irradiation of the specimens will be conducted inside the gamma irradiation facility, which will consist of two identical hot cells positioned back-to-back, each occupying an area 20 ft by 20 ft by 20 ft high. The size of an individual hot cell was dictated by the requirement that the cell be sufficiently large to simultaneously accommodate two 400-hp motors. A pool for storage of radioactive source materials, measuring 20 ft by 10 ft by 20 ft deep (or larger), will adjoin the two cells. The cell walls will be constructed of high-density concrete to preclude the leakage of radiation through the walls. Penetrations will be needed through the walls for manipulator arms, utilities, controls, diagnostics instrumentation, active loading, leads, and dosimetry instrumentation.

Each cell will be equipped with a hydraulically-operated door designed with safety interlocks to prevent its being opened when the radioactive source is not submerged in the pool. A shielded-glass window for viewing the interior of each hot cell will be incorporated.

The roof over the storage pool will be removable so that the shipping casks containing the radioactive sources can be transferred into and out of the pool.

A 30-ton crane will be installed for transferring the shipping casks into and out of the pool and for transporting specimens from the test laboratory to the hot cells.

The source storage pool must meet minimum safety requirements, which will be fulfilled in part by inclusion of pool cleaning and cooling systems. The cleaning system will consist of an ionization filtration system, complete with pumping units.

Three cobalt-60 sources, each having a strength of 0.5 x 10^6 Curies, will be included in each hot cell to provide a maximum exposure rate capability of about 5.0 Mrad/hour.

4.5 STEAM/CHEMICAL-SPRAY EXPOSURE FACILITIES

Two stainless-steel pressure vessels are planned for conducting HELB exposures: a 3-ft-diam by 4-ft-high vessel and a 6-ft-diam by 10-ft-high vessel. The use of two vessels is the result of a practical decision to test small specimens (i.e., terminal lugs) in a small vessel and large items (i.e., motors) in a larger vessel. It did not appear efficient to inject steam into a 6-ft-diam by 10-ft-high vessel to test specimens occupying less than 1 ft^3. Table 2-1 identifies the volume of the test specimens and indicates in which vessel they should be tested. It should be noted that cable volumes are not listed, since their nominal volume is not representative of the volume the cable would occupy while wrapped around a mandrel inside the pressure vessel. The vessels will have a minimum design rating in accordance with the ASME code for 500°F/150 psig superheated steam. The vessels will be equipped with penetrations and controls for water, steam and chemical-spray systems, and electrical leads for energizing specimens during testing.

Steam will be supplied by a 200-bhp generating system consisting of a boiler, feed pump and filter. To obtain superheated steam conditions at 400°F for 20 minutes inside the pressure vessels, the steam will be passed through a superheater prior to introduction into the pressure vessel. A single superheater of the stored heat-bed type with a 200-kW capacity is recommended for use with both vessels. The size of the unit will be approximately 4.5 ft in diameter by 10 ft long with 3-in inlet and outlet pipes. The flow of steam from the superheater to the pressure vessel will be regulated by two control valves. A temperature/pressure recorder will be used for monitoring the conditions inside the superheater.

The chemical spray will be prepared in a mixing tank and pumped into the vessel. A flowmeter will be used to monitor the flow rate of the spray over the specimens, and a pH meter will be used to monitor the acidity of the chemical solution.

Pressure and temperature inside the pressure vessel will be monitored by pressure gages for visual observations and by pressure transducers and thermocouples whose outputs will be recorded on strip charts.

4.6 STRUCTURAL TEST AREA

An erector-set arrangement of steel I-beams, comprising a "strong-back", will be necessary to conduct structural and force tests on some specimens such as valve actuators following an HELB exposure. The strong-back is constructed of 12-in I-beams in a 12-ft x 12-ft x 16-ft-high, reinforced-box arrangement mounted on a steel base plate.

4.7 ELECTRICAL TEST AREA

Operational aging and electrical functional tests will be conducted at this test station. This station will include various power supplies to operate different kinds of electrical specimens. A high-power (~500 kW) source with a three-phase ac voltage level, variable from 110 to 575 V, will be available. In addition, two 10-kW dc power sources, with voltage variable from -125 to +125 V and with a ground return potential of +250 V, are recommended for the test area.

The provision of ammeters and voltmeters for electrical measurements is addressed in Table 4-2 of Section 4.9.

A water immersion tank (25 ft long by 5 ft wide by 5 ft deep) is provided in this area to permit measurement of insulation resistance and dielectric properties of cables.

A dielectric strength test set with a minimum capability of 40 mA @ 50 kV ac and a high-voltage Schering or transformer bridge are included.

4.8 PNEUMATIC/HYDRAULIC TEST AREA

A pneumatic/hydraulic test area will drive pneumatic equipment such as actuators during functional tests and operational aging. This area will be equipped with a 5,000-psig hydraulic supply and a 6,000-pisg compressed-air or nitrogen supply with a storage receiver.

4.9 TEST CONTROL AND DATA ACQUISITION CENTER

Test control and monitoring equipment, as well as data acquisition instrumentation, will be located in a center separate from the laboratory. This instrumentation will control and monitor all environmental test conditions and specimen responses. In addition, a computer comparable to one of the CDC Cyber 171 series will be located in the center for purposes of off-line data analysis.

The equipment and instrumentation planned for installation in the center are listed in Table 4-2.

4.10 SPECIAL HANDLING EQUIPMENT

For transporting specimens inside the stockroom and test laboratory, two overhead cranes are recommended.

- one 10-ton crane with 20-ft span
- one 30-ton crane with 45-ft span.

Table 4-2. Test Control and Data Acquisition Instrumentation

Quantity	Equipment Type	Approx. Cost
2	pH meters	$ 1,500
2	Chemical-spray flowmeters	400
2	Chemical-solution pumps	480
2	Control valves	20,000
2	Two-pen millivolt/temperature recorders	5,000
1	Temperature/pressure recorder	20,000
2	Pressure transducers	1,200
2	Temperature transducers	1,200
2	Pressure gages	600
2	Voltmeters (0-750 V ac)	100
2	Multi-amp ac ammeters (10-10,000 mA ac)	1,000
2	Multipoint temperature recorders (24 points, 0-400°F)	6,000
1	Multimeter (1,000 V ac dc, 0-20 Ω)	100
1	Megohmmeter (50 kΩ to 5 TΩ, 10-100 V dc)	1,000
2	Test consoles	
	16 Current meters (5 A movements, use with transformers)	640
	16 Current transformers (meter type)	240
	2 Potential meters	100
	16 Auto transformers (0-140 V @ 10 A)	640
	16 Current (load) transformers (Pri 120 V, Sec 24 V @ 1.5 kVa)	3,500
	6 High-Pot transformers (Pri 240 V, Sec 600 V @ 1 kVa)	600
	2 (3φstack) auto transformers (Pri 208 V, Sec 280 V @ 4 A)	250
	2 Switch panels	400
	2 Cabinets (console)	700
2	Vibration monitors	1,200
2	Accelerometers	800
	TOTAL	$67,650

5. SUPPORT LABORATORIES AND MACHINE SHOP

5.1 SUPPORT LABORATORIES

Physical sciences laboratories for detailed testing and analysis of specimens and for instrument calibration will be included to support the qualification test laboratory and gamma irradiation facility. These laboratories will be housed in a single, large room divided into separate areas for each of the physical sciences. The salient functions of each laboratory are described in the following list:

- Metrology Laboratory

  The metrology laboratory will be used for the calibration and testing of monitoring instruments.

- Microscopy Laboratory

  This laboratory will be used for microscopic analysis of failed components and materials following an HELB exposure to determine their failure modes.

- Chemical Analysis Laboratory

  The chemical analysis laboratory will provide general chemical analysis support to the test laboratory. Functions to be performed include preparation of the chemical solution and the distilled water used in the HELB vessel and determination of the pH of the distillate to be recirculated in the HELB vessel.

- Electronics Laboratory

  The functions of the electronics laboratory will include the fabrication of energizing circuits, functional check circuits and the calibration and maintenance of electrical and electronic instruments.

- Materials Laboratory

  Testing of tensile strength, elongation and hardness of materials will be conducted in the materials laboratory.

- Radiation Calibration Laboratory

  Instruments used for dosimetry in the radiation facility will be calibrated periodically in this laboratory. The calibration equipment will also be checked at regular intervals by procedures traceable to standards of the National Bureau of Standards.

The types of equipment that will be provided in the support laboratories are illustrated by the list of typical instruments in Table 5-1. Based on the cost of the instruments listed and allowing approximately 50 percent more for instruments not listed, the amount budgeted for equipping the support laboratories was $300,000.

5.2 MACHINE SHOP

The machine shop will contain the tools needed for the fabrication of test fixtures and for the modification and repair of test equipment. Table 5-2 lists the machine shop tools and their cost.

Table 5-1. Typical Support Laboratory Equipment

Metrology Laboratory

- Meter calibrator
- Scope calibrator
- Frequency standard, distortion analyzer
- Monitor for NBS frequency calibrator
- Temperature standard
- Mechanical standards
- Flowmeter calibrator
- Dead weight pressure gage tester

Microscopy Laboratory

- Electron microscope
- Optical microscopes

Chemical Analysis Laboratory

- Distillation analysis equipment
- Spectral analyzers
- H_2O distiller
- Buffer test tube

Electronics Laboratory

- Digital multimeters
- CRT oscilloscope

Materials Laboratory

- Instron tensile strength test unit
- Gurley stiffness tester
- Precision penetrometer (hardness tests)
- ASTM cutting dies

Radiation Calibration Laboratory

- Dosimetry calibrator
- Scaler and timer
- Gamma scintillator
- Spectrophotometer

Miscellaneous Equipment (beakers, tubes, clamps, etc.)

Table 5-2. Machine Shop Equipment

Equipment	Approximate Cost ($)
Drill Presses	
Fosdick Radial 5-ft Swing	9,000
Fosdick 12 in	850
Fosdick 2 spindle 24 in	2,500
South Bend 14 in	250
Lathes	
Pratt & Whitney 16 in	8,000
Pratt & Whitney 16 in	8,000
Monarch 10-in Tool Room Lathe	6,000
Derbyshire Jewellers Lathe	3,000
Milling Machines	
3 Bridgeport Turret Hd. 36-in Tables	9,300
Ames Horizontal Bench	2,500
Shapers	
G & E 16 in	3,600
Band Saws	
2 Do-All Band Saws	4,900
Cut-Off Saw	
Racine, 6-in x 6-in capacity	250
Grinding Machines	
B&S Surface Grinder	3,400
Boyar Shultz Surface	2,600
B&S Cylindrical	4,200
Small Grinders	
Jarvis Flexible Shaft	125
Delta Pedestal	150
Blount (Snagging)	125
Standard (Pedestal)	150
Sheet Metal Equipment	
Pexto Shear (Power Shear, 48 in)	1,100
Pexto Shear, 30 in	650
Barth Box Brake	450
Pexto Brake	450
Pexto Rolls	350
Diacro Brake	500
Dries & Krump Brake	800
Welding Machines	
Airco Heliarc Welder ac-dc	9,000
General Electric 200 A dc	4,300
Federal Spot Welder	950
Punch Press	
Waterbury-Farrell, 40 ton, 7-in stroke	1,300
Jig-Borer	
Pratt & Whitney Vertical	18,000
Engraving Machine	
Gorton 2 Dimensional	1,800
Filing Machine	
Cochrane	250
Inspection Equipment	
Bausch & Lomb Comparator	13,000
Sheffield Comparators	500
Rockwell Hardness Tester	600
Gage Blocks	850
36-in x 36-in Surface Plate	350
Precision Measuring Equipment	10,000
TOTAL	134,100

6. SERVICE FACILITIES

The service facilities, which will provide the necessary support functions for the efficient operation of the laboratory, are described in this section. Table 6-1 lists the equipment to be procured for these services and the approximate costs.

- Mailroom

  Functions of the mail service will include the distribution of internal and incoming mail and the wrapping and posting of outgoing letters and packages. The costs of a mailing machine and additional mailroom equipment are listed in Table 6-1; these costs were obtained from an office equipment supplier's catalogue.

- Receiving Department

  The receiving department, which will be located adjacent to the storage room, will be responsible for the receipt, storage and shipping of test specimens, spare parts and raw materials.

  Access to the receiving department and storage room will be controlled for purposes of security and quality control.

- Photography Shop

  The photography shop, including a darkroom, will provide photographic and reprint services for the laboratory. During qualification testing, a photographer will be available to photograph test equipment arrangements and test specimens for use in test reports.

- Publications

  Drafting, layout, blueprints, reproduction and printing, and all other services related to the publication of test reports will be provided to the laboratory by the publications department. The cost of printing presses and associated equipment presented in Table 6-1 are based upon current purchase prices.

- Building Services

  General building services such as painting, carpentry and grounds maintenance will be provided by the building services department.

- Dispensary

  A dispensary will be located in the building to provide immediate emergency treatment of illnesses and conditions arising from industrial accidents. First aid stations will be located at various places throughout the building.

- Cafeteria

  A cafeteria will be provided to supply a hot luncheon meal to employees during the five-day work week. Limited food and vending machine service will be available at all other times when the laboratory is open.

Table 6-1. Equipment for Service Facilities

Service	Equipment	Approximate Cost ($)	
1. Mailroom	• 1 Mailing machine	2,700	
	• 3 Scales (first class, parcel post and foreign mail)	500	
	• 2 Roll cutters	100	
	• 2 Tape machines	400	
	• Wrapping tables	300	
			4,000 subtotal
2. Receiving Department	• Binding tools	4,000	
			4,000 subtotal
3. Photography Shop	• 35-mm camera	700	
	• 2-1/4 x 2-1/4 camera	1,500	
	• 4 x 5 view camera	500	
	• Instant camera	200	
	• Motion picture camera	2,500	
	• Processing equipment	500	
	• Nitrogen burst temperature controller	4,000	
	• Contact printers	200	
	• Enlarger	1,000	
	• Washer	400	
	• Dryer	1,000	
			12,500 subtotal
4. Publications	• Chain delivery press	9,000	
	• Automatic press	11,000	
	• Electrostatic platemaker	12,500	
	• Platemaker (metal plates)	1,200	
	• Offset camera (35-in by 35-in frame)	6,500	

Table 6-1. Equipment for Service Facilities (cont'd)

Service	Equipment	Approximate Cost ($)
	• Spiral binder	2,500
	• Paper cutter (17 in by 22 in)	3,000
	• Stapling machine	750
	• Reproduction machine	To be pro-rated over first 5 years
		46,450 subtotal
5. Building Services	• Engineering and plumbing tools	3,000
	• Electrical shop tools	12,000
	• Cleaning machines (vacuums, floor machines, brooms)	2,700
	• Paint shop	2,000
		19,700 subtotal
6. Dispensary	• Examination table	500
	• Scale	200
	• Stretcher	100
	• Medical and first aid supplies	2,000
		2,800 subtotal
7. Cafeteria	• 2 Freezers	4,000
	• 2 Hot tables	10,000
	• 22 Tables (seat 6)	2,200
	• 132 Chairs	6,600
		22,800 subtotal
		$112,250 TOTAL

7. BUILDING REQUIREMENTS

7.1 GENERAL

It was considered advisable that the laboratory facility be located in a semi-rural area due to the socio-psychological consequences of constructing a laboratory equipped with a nuclear radiation test facility in the vicinity of a highly-populated area. Because of its possibly remote location, the building should be self-contained and capable of supplying all operational needs as practical. In preparing a budget, land costs were not included in the overall estimate. Water, sewer, electricity and fire protection were assumed to be readily available; the cost of connections for these utilities was not included in budget summaries.

A single building, comprising administrative and engineering offices, a high-bay test laboratory and a secure gamma irradiation facility adjoining the test area, has been designed for the site. An overall view of the planned facility is illustrated in Figure 7-1.

With the exception of the adjoining irradiation facility, the building will be constructed of concrete blocks; low-maintenance materials will be used for window frames and doors. The irradiation hot cells will be constructed of high-density concrete.

The entire structure will cover approximately 55,000 sq ft of floor space, including a 26,000-sq-ft area (170 ft long by 150 ft wide) set aside for office space. A second 26,000-sq-ft area will comprise the main laboratory and test areas, which will have a high bay (20-foot ceiling). The irradiation facility will require an additional 3,600 sq ft of floor space. A 12-foot-wide loading dock will span the width of the building at the rear and will be accessible by a railroad line and a paved truck thoroughfare. Test equipment, test specimens and raw materials will be delivered to the loading dock and then brought into the laboratory.

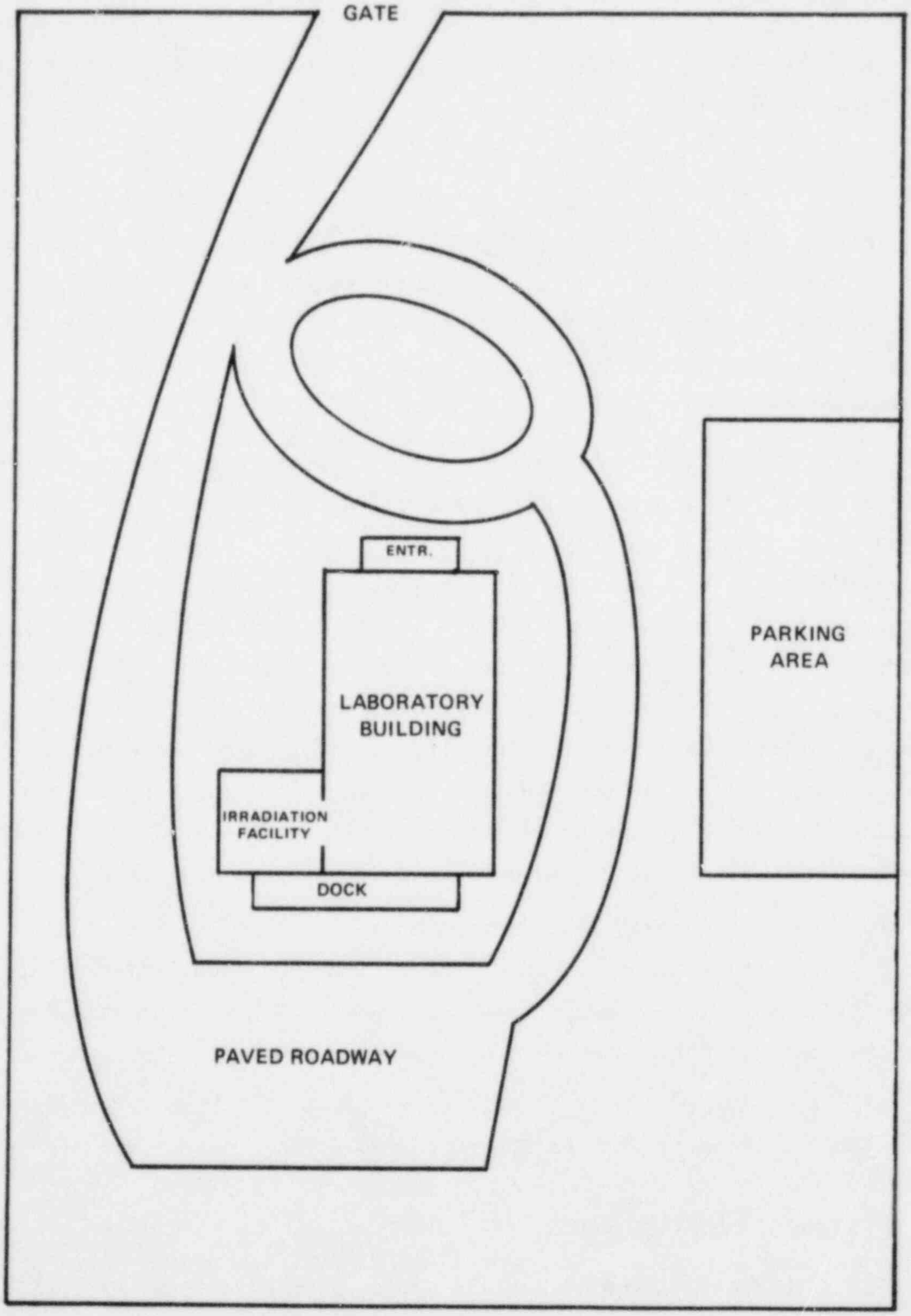


Figure 7-1. Plan View of Laboratory Site (Phase I)

The interior layout of the building is illustrated in Figure 7-2 and described in subsequent paragraphs.

7.1.1 Test Laboratory

The test laboratory, occupying 10,000 sq ft, will be located at the rear of the building and will open onto the loading dock. The test area has been designed with a 20-ft-high ceiling to accommodate the 10-ft-high pressure vessel, an overhead crane and the handling of large test specimens.

The test area has been designed for the sequential flow of specimens between individual test stations in a circular manner. In a typical test sequence, specimens brought from the storage room will be delivered first to the thermal aging oven located just inside the doorway. Upon completion of thermal aging, the specimens, which must undergo operational aging and functional tests, will be transferred to either the electrical or pneumatic test area. Specimens will subsequently be subjected to vibrational aging on the vibration tables located opposite the storage room access door. The specimens will then be moved from the vibration tables to the irradiation facility. Upon completion of irradiation, all specimens will be brought back to the test laboratory and deposited at the HELB test area.

Upon completion of HELB testing, the specimens will be moved to any one of three test areas (structural, electrical, or pneumatic/hydraulic), depending upon the type of specimen and its specific requirements for post-test checkout and inspection.

All test specimens will finally be returned to the storage room to be crated for shipment back to the supplier, for storage or for scrapping.

7.1.2 GAMMA IRRADIATION FACILITY

Since this facility will contain radioactive materials, special requirements have been imposed on its design, and access to the facility

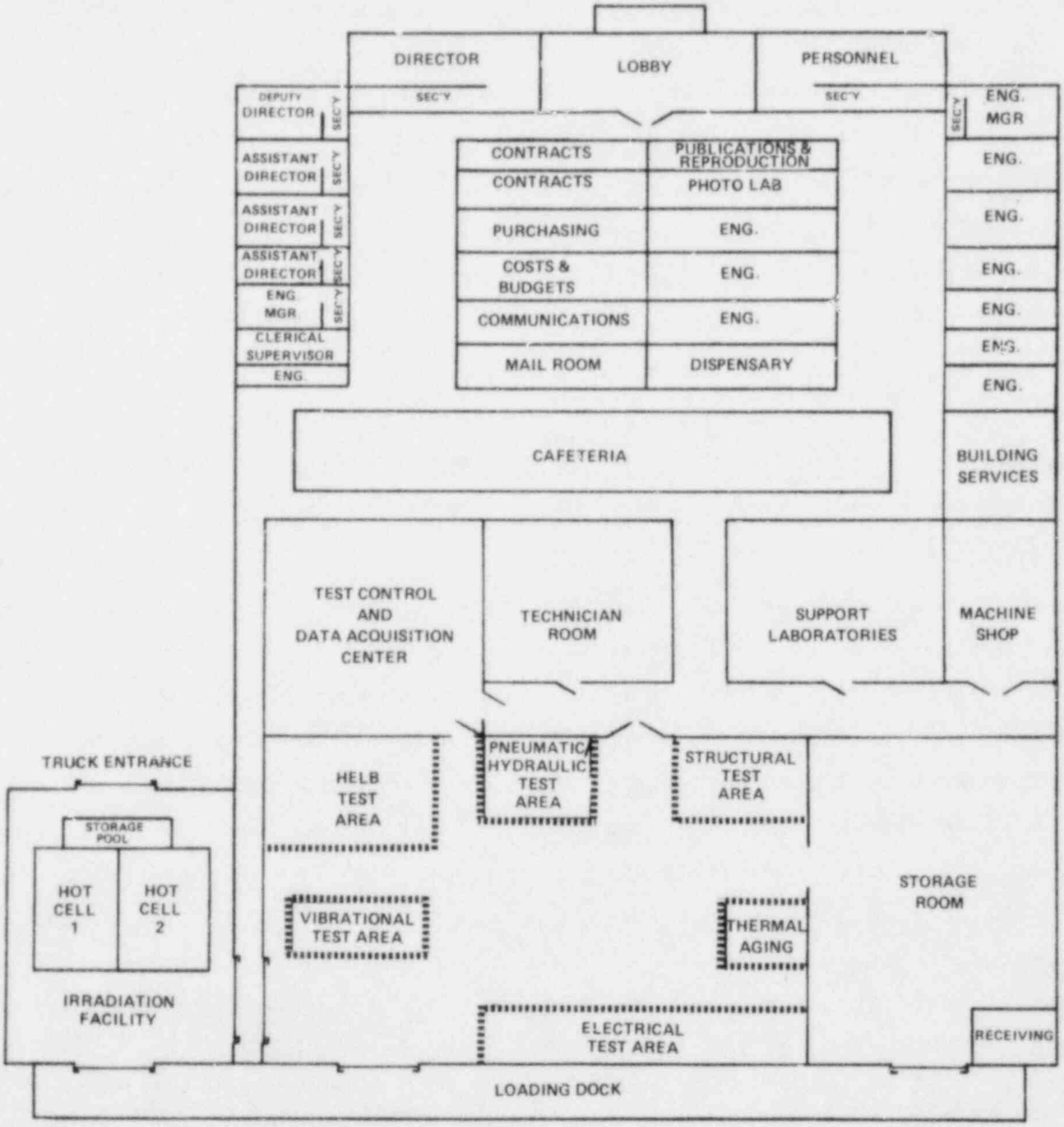


Figure 7-2. Plan View of Laboratory Building (Phase I)

will be very carefully controlled. The facility will occupy 3,600 sq ft and will be located adjacent to the main test laboratory. Test specimens will be irradiated in two hot cells, which have been designed as 20-ft cubes positioned side by side. Adjoining the hot cells will be a test control and instrumentation area and a 20-ft-long by 10-ft-wide by 20-ft-deep pool for storage of radioactive source materials, as illustrated in Figures 7-3 and 7-4. The size of each hot cell will permit simultaneous irradiation of two 400-hp motors. The walls of the hot cells will be constructed of high-density concrete; the outer walls of the building will be constructed of 4-in-thick concrete blocks with brick facing.

The hot cells will be equipped with hydraulically operated doors for placing test specimens in the chamber. The doors will have safety interlocks to prevent their being opened while the radioactive source is not submerged in the pool. Shielded-glass windows for viewing the interior of the hot cells will be included.

The cell doorways will open into the test control area. An entrance for personnel will be located between the corridor and the control area which can be opened only by the insertion of an identification card and the entering of a coded sequence of numbers. A large door designed with a safety lock will open into the main test bay and will function as the main passageway between the two laboratories; a second door will open onto the loading dock for receiving specimens. Trucks will be able to drive up to an entrance adjacent to the storage pool so that the shipping casks containing the radioactive sources can easily be loaded and unloaded. This area must have access for large cobalt-60 shipping casks and an overhead crane of at least 30-ton capacity for transferring casks into and out of the pool.

Penetrations in the wall of each hot cell will be needed for test controls and for manipulator arms used to position radioactive sources and/or specimens inside the hot cell.

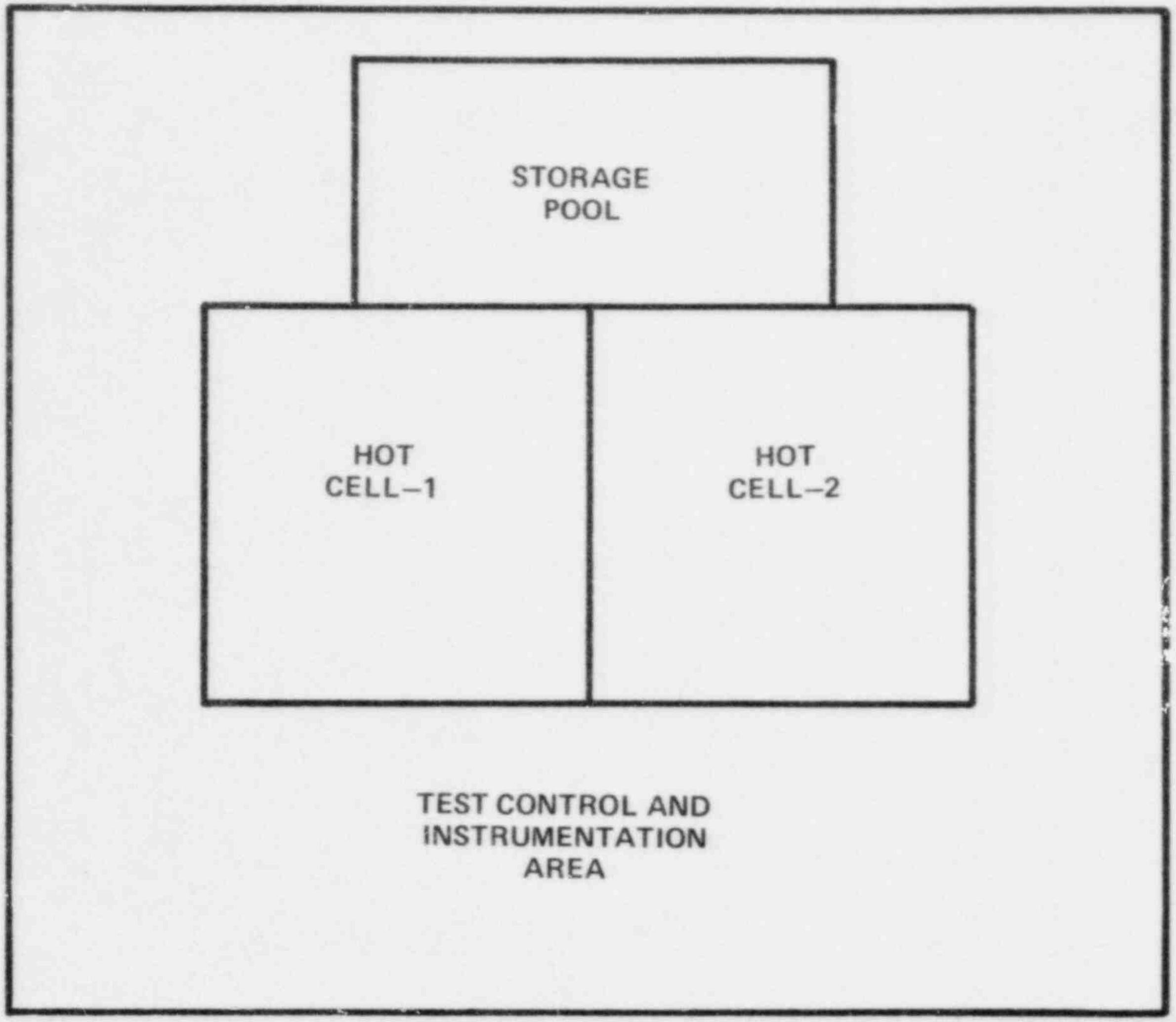


Figure 7-3. Plan View of Irradiation Facility Layout

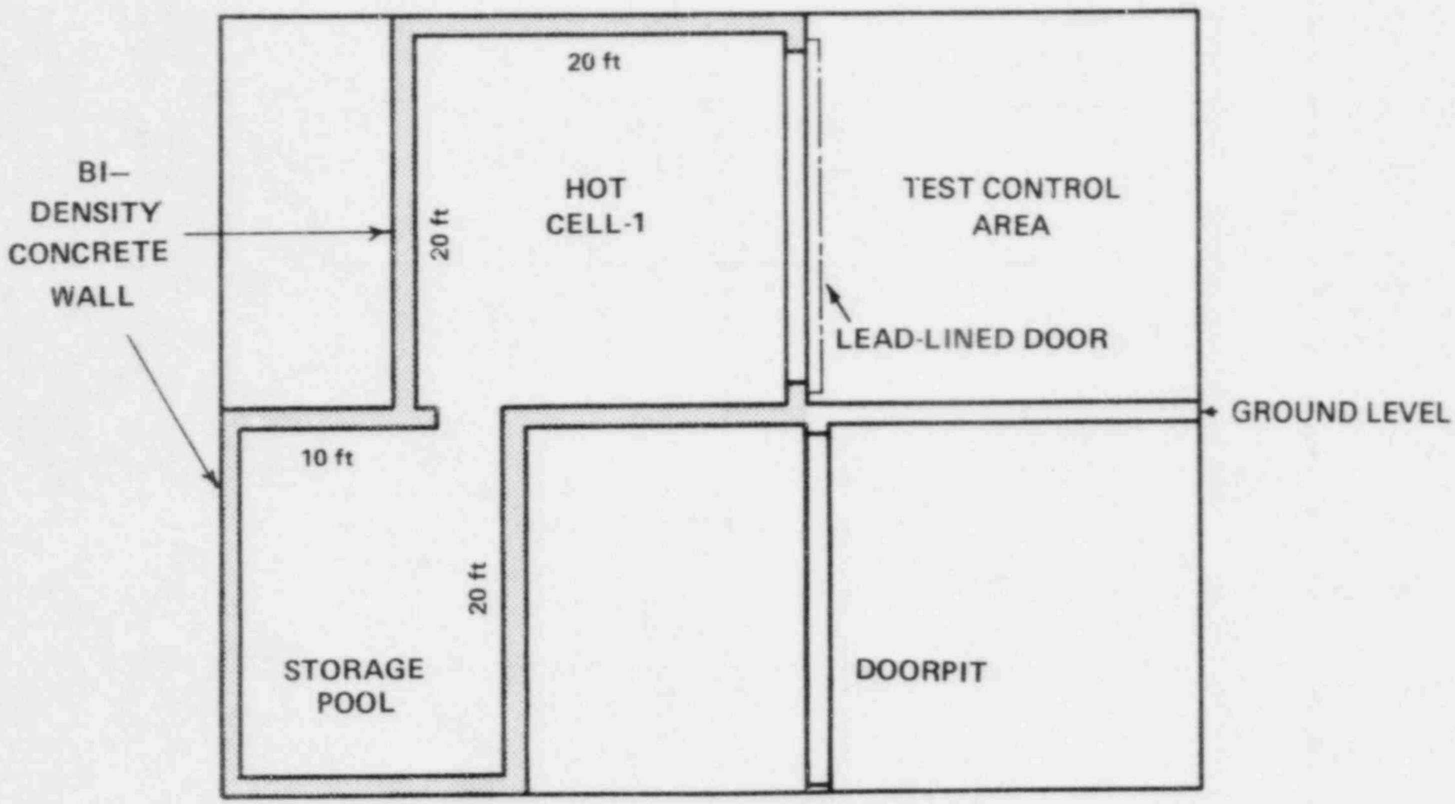


Figure 7-4. Containment Area of Irradiation Facility (Elevation)

As discussed in Section 4.4, the storage pool will be equipped with a cleaning system and a cooling system. Mechanical handling systems for lifting the cobalt sources from the pool into the hot cells will also be provided.

Prior to construction, a detailed design specification for the irradiation facility will be prepared. To this end, analyses of shielding requirements, safety standards and cleanup systems must be performed.

7.1.3 OFFICES

Lobby

Entry to the building will be gained through the lobby, where visitors will be greeted by the receptionist. Security will maintained by the receptionist, who will issue passes to visitors before allowing them to proceed to their approved destinations. The switchboard operator will be located in a small office behind the reception area. Double glass doors will separate the office area from the lobby.

Administrative Offices

As shown in Figure 7-2, the offices will be arranged around two corridors extending halfway down the length of the building and will occupy approximately 13,000 sq ft of floor space on the main level of the building. The personnel office will be located adjacent to the lobby, readily accessible to applicants.

The large end office will be reserved for the laboratory director, and a smaller, adjacent office will be provided for the director's secretary. The deputy director's office will be located next to that of the director, with similar secretarial space provided. Six individual offices designed for the use of the assistant directors and their secretaries will be arranged lengthwise along one side of the building.

Nine of the administrative and engineering managers will be assigned separate offices, eight of which have adjacent rooms in which either a secretary or a clerk will be located. The secretarial/clerical supervisor will have a single office in the administrative office area. A nurse, available to provide emergency first aid, will be stationed in the dispensary, which will be located toward the rear of the office area. The photography room, also located in the administrative office area, will provide support to the security office with photographs for employee badges and to the engineering department with photographs of equipment tests for incorporation into test reports. Incoming and outgoing mail will be processed in the mailroom, which will also be located in the office area.

Engineering Offices

An additional 3,000-sq-ft area, divided into ten offices and including a drafting room and conference room, will be available to accommodate an engineering staff of fourteen.

Cafeteria

A 7,500-sq-ft cafeteria capable of accommodating the entire staff will be located between the administrative and engineering offices and the test laboratory.

Support Facilities

The building services, support laboratory, technicians' room (providing desks for 20 technicians), machine shop, and test control and data acquisition center will provide close technical support to the test laboratory and therefore will be located near the laboratory; the support facilities will occupy a 10,500-sq-ft area. A glass partition will separate the test control and data acquisition center from the test laboratory, allowing personnel to view an ongoing test.

The storage room will occupy another 5,000 sq ft of floor space alongside the test laboratory at the rear of the building. The storage room has also been designed with a 20-ft-high ceiling to allow for an overhead crane to transport large specimens. A 12-ft-wide rolling overhead door will separate the storage room from the test laboratory.

7.2 CONSTRUCTION COSTS

The cost of erecting a laboratory building constructed of concrete blocks with brick facing was estimated as $\$60/ft^2$, based on figures derived from the 1978 Dodge Construction Systems Costs (Reference 2). This is a comprehensive estimate, including site excavation, the building foundation, the structure and roof, finished interior walls and carpets, heating, ventilation, and air conditioning. All specialized interior equipment, such as exhaust fans in the laboratories or restaurant facilities in the cafeteria, as well as minimal landscaping of the grounds and fencing and paving, are included in the cost estimate. Using the $\$60/ft^2$ estimate, the total construction cost of the proposed 56,500-sq-ft laboratory building, including the test laboratory, offices and gamma irradiation facility minus the hot cells, was therefore estimated as $3,390,000.

8. TASKS TO PLAN, BUILD AND INITIATE OPERATION OF LABORATORY

8.1 PRELIMINARY HIRING OF STAFF

Initially, a small staff of four persons will be hired to begin planning and executing the tasks required to put the laboratory into operation. The first person appointed will be the Director, who will be responsible for hiring three additional persons to support the effort.

8.2 SITE SELECTION

As recommended in Section 7, the laboratory should be located in a semi-rural area due to the social sensitivity about constructing a laboratory which uses radioactive materials in a highly-populated neighborhood. Therefore, the site of the laboratory should be selected with this consideration in mind.

8.3 PREPARATION OF SPECIFICATIONS

8.3.1 Facility Design Specifications

Bids will be solicited from architectural and engineering (A & E) firms to develop the detailed design of the building. The A & E solicitations will include architectural design specifications and cost proposals for the actual construction and installation of the building and facilities. It was estimated that a four man-year effort by the A & E firm awarded the contract will be required in a two-year period to prepare design specifications at an approximate cost of $300,000.

8.3.2 Test Equipment and Machinery Design Specifications

Procurement specifications will be prepared for the purchase of the test equipment and support equipment identified in Tables 4-1, 4-2, 5-1, 5-2 and 6-1. Less effort will be expended in preparing specifications for commercially available equipment such as the thermal aging ovens and vibration tables identified in Table 4-1 and the data acquisition instruments listed in Table 4-2. The support laboratory equipment (Table 5-1), machine shop equipment (Table 5-2) and service facilities equipment (Table 6-1) should also be readily available.

Since some of the test equipment discussed in this study, such as the radiation facility, HELB test vessels, and mechanical, electrical and pneumatic/hydraulic cycling facilities, are of a specialized nature, individual performance specifications will be generated for each type of equipment.

It was estimated that a six man-year effort in a two-year period will be required to prepare the performance and procurement specifications. The cost of preparing the specifications will be approximately $450,000.

8.4 STAFF INTERVIEWS AND HIRING

When the specifications have been completed and sent out for bids, preliminary effort should be directed toward determining staff requirements. The director will be responsible for the interviewing and hiring of the staff.

8.5 ORDERS FOR BUILDING EQUIPMENT AND FURNISHINGS

- Building

  Following the completion of the building design specifications, a construction firm will be awarded a contract to construct the facility.

- Test Equipment

  Bids will be solicited from qualified firms for the manufacture and installation of the test equipment. (The request for bids will be distributed to a number of manufacturers in a competitive manner.)

- Furniture

  An order will be placed with a furniture supplier for staff office furnishings.

8.6 EQUIPMENT INSTALLATION

Upon delivery, the test equipment must be connected to appropriate outlets, generating systems and exhaust systems. Special mounting fixtures will be fabricated at this time.

8.7 OPERATIONAL CHECKOUT

Six months prior to the opening of the laboratory for qualification testing, several spare dummy specimens will be tested to ensure proper operation of the test equipment and/or to make adjustments or modifications as necessary.

9. ANALYSIS OF OPERATING PERIOD

9.1 GENERAL ASSUMPTIONS FOR PHASE I

The mode of operation for Phase I of this study was defined as one in which test specimens will be processed sequentially through the laboratory. Consequently, it was initially intended that a single HELB test facility be used. However, since specimen size varies significantly, it seemed more practical that the size of the test facilities should correspond to that of the test specimens. For example, it appeared impractical to test terminal lugs measuring 3 in by 1 in by 1 in in a pressure vessel large enough to accommodate a 3-ft-diam by 6-ft-high, 400-hp motor. Consequently, it was decided that two HELB pressure vessels would be utilized: a 3-ft-diam by 4-ft-high "small" vessel and a 6-ft-diam by 10-ft-high "large" vessel. Smaller items will be grouped together and tested simultaneously in the small vessel; larger items will be tested separately in either the small or the large vessel, depending on their size. Accordingly, the development of the estimates of the resource requirements and costs associated with constructing, equipping, staffing, and operating the laboratory in Phase I was based upon the following assumptions:

- Large specimens will be tested as single units; smaller specimens will be combined and tested in groups whenever possible;
- The HELB test facility will consist of a large pressure vessel and a small pressure vessel, which will be utilized concurrently;
- The large HELB test vessel, in which well over half the specimens are to be tested, will be kept in continuous operation.

9.2 OPERATING PERIOD ANALYSIS

Table 9-1 lists all of the 135 specimens of Class 1E equipment with the estimated times to conduct each element of the entire test program. This is consistent with the test sequence described in Section 3, which is illustrated by a flow diagram in Figure 9-1.

The result of an an sis to separate equipment according to size is included in Table 9-1. The number of tests to be performed in the large or small HELB test vessel, for each category of Class 1E equipment, is listed in the last two columns ahead of the final, "Remarks" column. Twenty-seven tests will be conducted in the large vessel and fourteen tests in the small vessel.

Table 9-1 also lists the time required to run each test in the program sequence. The setup time and post-test evaluation time, on a single unit or a group of specimens, were estimated from prior testing experience and are listed in columns 2 through 22. The time span necessary to process all 135 specimens was then calculated by multiplying the longest test time by the number of tests to be performed, as explained in the following paragraphs.

The HELB test, which will take the longest time to complete (six weeks), will regulate the time of the entire test sequence and could be a potential bottleneck in the laboratory. It was therefore assumed that the large HELB vessel would be maintained in continuous operation. Consequently, enough equipment was provided at the other test facilities to permit such continuous operation. This equipment includes a small and large oven, a small and large vibration table, one operational aging station, and two radiation hot cells.

Since twenty-seven tests will be conducted inside the large vessel and only fourteen tests will be conducted in the small vessel, it seemed reasonable to demand that only the large vessel be operated on a continuous basis. Since the HELB test takes six weeks to complete, the time to complete twenty-seven HELB tests was estimated as 162 weeks. The fourteen tests to be conducted in the small HELB test vessel will be run concurrently with those in the large vessel, but they will take less than 162 weeks to complete.

The time required to process 135 test specimens in the Phase I qualification test program was estimated as four years, on the following basis. A review of Table 3-2 shows that the longest time required for the tests preceding and following the HELB test is 23 weeks, which applies to item 25 (Rotometers); adding this to the 162-week HELB testing time yields a total processing time of 185 weeks, or 3.6 years. Fifteen weeks, or 8% of the total test time, were added to allow for possible delays due to periodic maintenance and equipment repair, and eight weeks were added to allow for delays in delivery of the test specimens and other unexpected delays. The sum of the testing time and the periods allowed for maintenance, repair and potential delays leads to the estimate of four years to complete the program of testing the entire backlog of 135 specimens.

Table 9-1. Breakdown of Qualification Testing Time (Numbers are test times in weeks)

CLASS 1E EQUIPMENT	BASELINE TEST			THERMAL AGING			AGING & ACCIDENT IRRADIATION			VIBRATIONAL AGING			OPERATIONAL AGING			HELB TEST			POST-HELB TESTS			NUMBER OF HELB TESTS REQUIRED		REMARKS
	set up	run test	†	set up	run test	†	set up	run test	†	set up	run test	†	set up	run test	†	set up	run test	†	set up	run test	†	small vessel	large vessel	
1. Transmitters	1	1	0.5	2	1	0.5	0.5	3	0.5	1	1	0.5	1	1	0.5	1	4.5	0.5	0.5	1	0.5	-	1	
2. Actuators (Electric)	3	1	0.5	2	1	0.5	1	3	0.5	1	1	0.5	2	1	0.5	1	4.5	0.5	1	0.5	0.5	5	-	
3. Actuators (Pneumatic) (Not 1E)	3	2	0.5	2	1	0.5	1	3	0.5	1	1	0.5	2	2	0.5	1	4.5	0.5	1	0.5	0.5	-	4	
4. Thermocouple	1	1	0.5	1	1	0.5	0.5	3	0.5	1	1	0.5	1	1	0.5	1	4.5	0.5	0.5	1	0.5	1	-	
5. Resistance Temperature Device (RTD)	1	1	0.5	1	1	0.5	0.5	3	0.5	1	1	0.5	1	1	0.5	1	4.5	0.5	0.5	1	0.5			
6. Limit Switch	2	1	0.5	1	1	0.5	0.5	3	0.5	1	1	0.5	1	1	0.5	1	4.5	0.5	0.5	1	0.5			
7. Differential Pressure Switch	3	1	0.5	1	1	0.5	0.5	3	0.5	1	1	0.5	2	1	0.5	1	4.5	0.5	1	1	0.5	1	-	
8. Pressure Switch	2	1	0.5	1	1	0.5	1	3	0.5	1	1	0.5	1	1	0.5	1	4.5	0.5	0.5	1	0.5			
9. Solenoid Valves	2	1	0.5	1	1	0.5	1	3	0.5	1	1	0.5	1	1	0.5	1	4.5	0.5	0.5	1	0.5	1	-	
10. Terminal Blocks	2	1	0.5	1	1	0.5	0.5	3	0.5	1	1	0.5	Δ	Δ	0.5	1	4.5	0.5	0.5	1	0.5	1	-	
11. Enclosure	2	1	0.5	1	1	0.5	0.5	3	0.5	1	1	0.5	1	1	0.5	1	4.5	0.5	0.5	1	0.5			
12. Radiation Monitoring System (ARCA)	3	1	0.5	2	1	0.5	1	3	0.5	1	1	0.5	2	1	0.5	1	4.5	0.5	1	1	0.5	-	1	
13. Radiation Monitoring System (Airborne - Particulate, Gaseous, Iodine)	3	1	0.5	2	1	0.5	1	3	0.5	1	1	0.5	2	1	0.5	1	4.5	0.5	1	1	0.5	-	1	Outside containment
14. Hydrogen Analyzer	3	1	0.5	2	1	0.5	1	3	0.5	1	1	0.5	2	1	0.5	1	4.5	0.5	1	1	0.5	-	1	Outside containment

NOTES:

† Post-test evaluation, including functional test, checkout, and facility setdown and clean-up.

Δ If terminal blocks include disconnects, cycle approximately 1000 times.

Table 9-1. Breakdown of Qualification Testing Time (cont.) (Numbers are test times in weeks)

CLASS 1E EQUIPMENT	BASELINE TEST			THERMAL AGING			AGING & ACCIDENT IRRADIATION			VIBRATIONAL AGING			OPERATIONAL AGING			HELB TEST			POST-HELB TESTS			NUMBER OF HELB TESTS REQUIRED		REMARKS
	set up	run test	†	set up	run test	†	set up	run test	†	set up	run test	†	set up	run test	†	set up	run test	†	set up	run test	†	small vessel	large vessel	
15. Terminal Lugs	1	1	0.5	1	1	0.5	0.5	3	0.5	1	1	0.5	1	1	0.5	1	4.5	0.5	0.5	1	0.5	-	-	With items 10 and 11
16. 300-V Instrument Cable	1	1	0.5	1	1	0.5	0.5	3	0.5	1	1	0.5	1	1	0.5	1	4.5	0.5	0.5	1	0.5			
17. 300-V Thermocple Cable	1	1	0.5	1	1	0.5	0.5	3	0.5	1	1	0.5	1	1	0.5	1	4.5	0.5	0.5	1	0.5	} 1 (items 16–18)	-	
18. 600-V Control Cable	1	1	0.5	1	1	0.5	0.5	3	0.5	1	1	0.5	1	1	0.5	1	4.5	0.5	0.5	1	0.5			
19(a) 5-kV Cable	1	1	0.5	1	1	0.5	0.5	3	0.5	1	1	0.5	1	1	0.5	1	4.5	0.5	1	1	0.5			
19(b) 5-kV Cable	1	1	0.5	1	1	0.5	0.5	3	0.5	1	1	0.5	1	1	0.5	1	4.5	0.5	0.5	1	0.5	} 1 (items 19(a)–19(b))	-	Outside containment
20. Motor	3	1	0.5	2	1	0.5	1	3	0.5	2	1	0.5	2	1	0.5	2	4.5	0.5	1	1	0.5	-	6	
21(a) Penetrations - Power Cables	3	1	0.5	1	1	0.5	0.5	3	0.5	1	1	0.5	1	1	0.5	1	4.5	0.5	0.5	1	0.5	-	4	
21(b) Penetrations - Control Cables	3	1	0.5	1	1	0.5	0.5	3	0.5	1	1	0.5	1	1	0.5	1	4.5	0.5	0.5	1	0.5	-	4	
21(c) Penetrations - Instrumentation Cables	3	1	0.5	1	1	0.5	0.5	3	0.5	1	1	0.5	1	1	0.5	1	4.5	0.5	0.5	1	0.5	-	4	
22(a) 600-V Power Cable	1	1	0.5	1	1	0.5	1	3	0.5	1	1	0.5	1	1	0.5	1	4.5	0.5	0.5	1	0.5			
22(b) 600-V Power Cable	1	1	0.5	1	1	0.5	1	3	0.5	1	1	0.5	1	1	0.5	1	4.5	0.5	0.5	1	0.5			
23. Connectors	1	1	0.5	1	1	0.5	0.5	3	0.5	1	1	0.5	1	1	0.5	1	4.5	0.5	0.5	1	0.5	} 1 (items 22(a)–24)	-	
24. Switchboard Wire	1	1	0.5	1	1	0.5	0.5	3	0.5	1	1	0.5	1	1	0.5	1	4.5	0.5	0.5	1	0.5			
25. Rotometers	3	1	0.5	2	1	0.5	1	3	0.5	2	2	0.5	2	1	0.5	1	4.5	0.5	1	1	0.5	1	-	
26. Neutron Monitors	3	1	0.5	2	1	0.5	0.5	3	0.5	2	1	0.5	2	1	0.5	1	4.5	0.5	1	1	0.5	-	1	
27. Level Switch	3	1	0.5	1	1	0.5	0.5	3	0.5	2	2	0.5	2	1	0.5	1	4.5	0.5	1	1	0.5	1	-	
28. Splices	3	1	0.5	1	1	0.5	0.5	3	0.5	1	1	0.5	1	1	0.5	1	4.5	0.5	0.5	1	0.5	-	-	Item 28 to be tested with cables.
Total No. of HELB tests																						14	27	

NOTES:

† Post-test evaluation, including functional test, checkout, and facility setdown and clean-up.

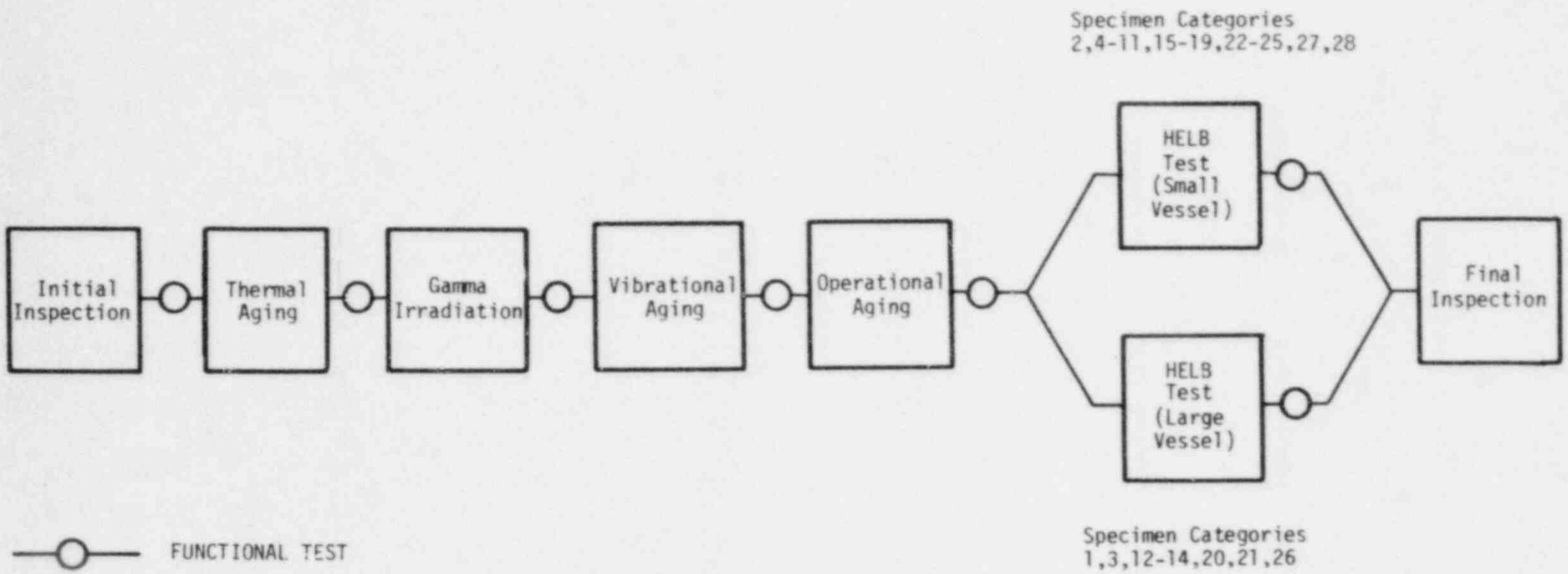


Figure 9-1. Phase I Test Sequence

10. STAFF REQUIREMENTS - PERSONNEL, SALARIES, FURNISHINGS

10.1 ORGANIZATION

The proposed staff organization is shown in Figure 10-1. A Deputy Director, who will report to the Laboratory Director, will be in charge of operations. Three Assistant Directors will head the areas of *qualification testing, administration* and *building and equipment*. The Qualification Testing Manager and his staff of engineers and technicians will be responsible for conducting aging and accident simulation tests. Providing support services to the qualification testing staff, but reporting directly to the Assistant Director of Qualification Testing, will be the Qualification Facility Supervisor, Instrumentation Supervisor, Support Laboratory Supervisor and the Computer Services Supervisor.

The managers and supervisors responsible for administrative functions, such as accounting, personnel, purchasing, storage, mailing, typing, publishing, and printing services, will report to the Assistant Director of Administration.

The managers and supervisors responsible for services related to the maintenance and upkeep of the building and grounds, security, food services and transportation will report to the Assistant Director of Building and Equipment.

A Quality Assurance Manager will report directly to the Deputy Director.

Two full-time consultants with prior experience in the qualification of Class 1E equipment are included to provide overall guidance to the laboratory. They will report to the Deputy Director.

The staff will be built up in steps as required to initiate formation of the laboratory and putting it into full-scale operation. The Laboratory Director will be the first person appointed. As previously indicated in

Section 8.1, he will select three other persons to assist him in planning and executing the tasks required to construct and equip the laboratory. One year before the scheduled completion of construction, the Personnel Manager will be hired; he will pursue the interviewing and hiring of the technical, administrative and service personnel. The staff will be put into service as required, eventually building up to a full-time staff of 127.

10.1.1 Laboratory Director

The Laboratory Director will be responsible for the effective operation of the laboratory. Specific duties will include overall planning, preparation of budgets, periodic evaluation of technical programs, and all activities pertaining to administrative and personnel concerns.

10.1.2 Deputy Director

A Deputy Director will assist the Laboratory Director in performing his duties. In the Director's absence, the Deputy Director will assume responsibility for functional operation of the laboratory.

Associated with the Director's office will be three assistant directors, each of whom will be responsible for a specific line of discipline. Brief descriptions of their respective responsibilities, and of the key people in each group, are given in the following paragraphs.

10.1.3 Assistant Director - Qualification Testing

The Assistant Director for Qualification Testing will be responsible for the maintenance of test equipment and the maintenance and programming of test specimens. He will also be responsible for the purchase of materials and spare parts. Two managers will assist him in carrying out these tasks.

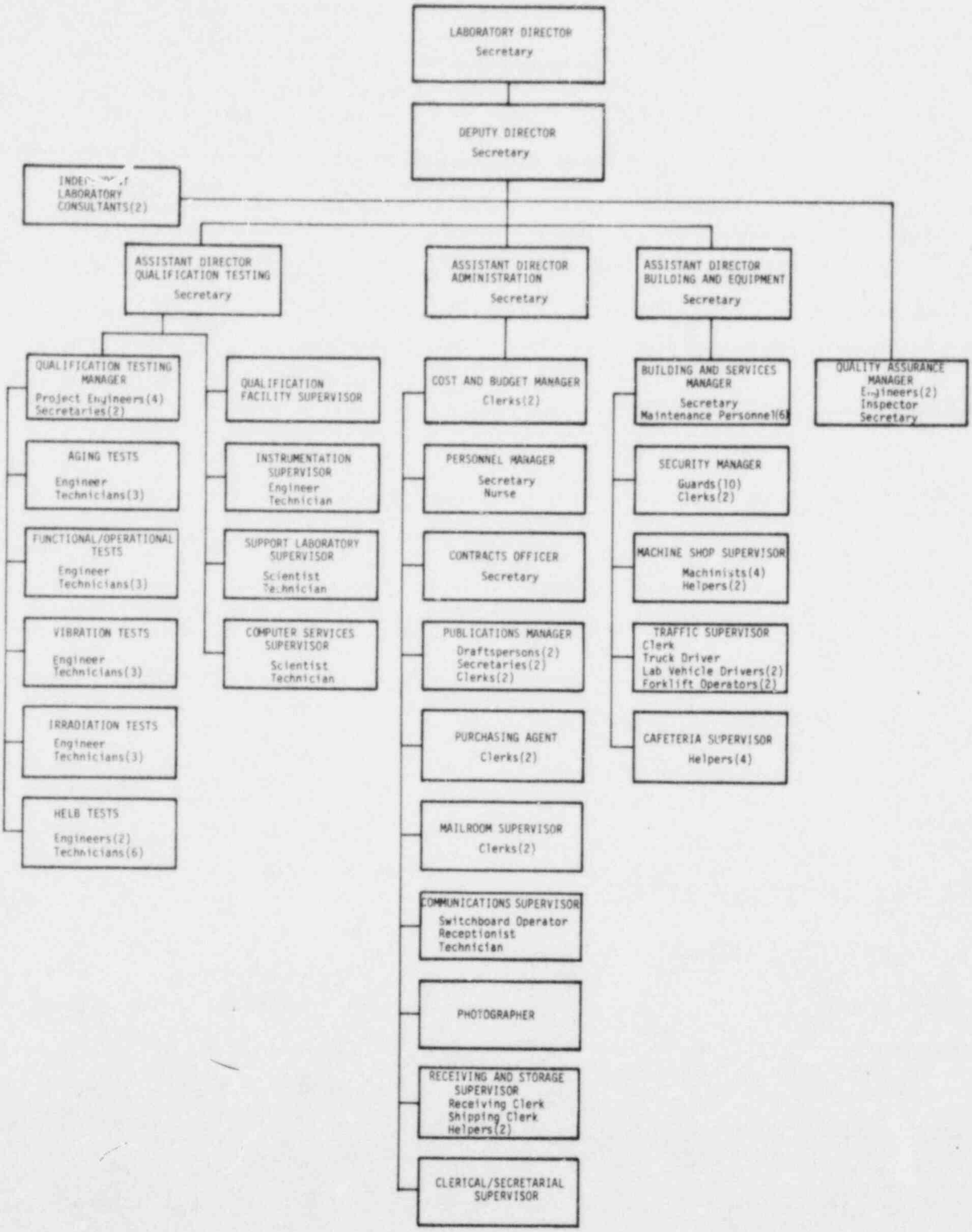


Figure 10-1. Recommended Staffing Level and Organization Chart for Phase I

Qualification Testing Manager

The Qualification Testing Manager and his staff of project engineers will be responsible for planning, conducting and documenting all tests performed on the specimens of Class 1E equipment. The manager will be responsible for the test schedule, control of project budgets, assignment of technical and support personnel to projects, and review of technical reports. The project engineers will be responsible for preparing test plans, supervising the technicians to ensure that test plans are followed, analyzing test results, and preparing test reports.

Qualification Facility Supervisor

The Qualification Facility Supervisor will be responsible for ensuring the proper functioning of all test equipment, including thermal aging ovens, functional/operational test stands, vibration shake tables, radiation laboratory equipment, and HELB testing facilities.

Instrumentation Supervisor

The Instrumentation Supervisor, with the assistance of an engineer and a technician, will be responsible for the proper functioning of data acquisition instrumentation and for ensuring instrument calibration on a scheduled basis.

Support Laboratory Supervisor

The support laboratory staff, under the direction of the Laboratory Supervisor, will provide the following laboratory services: metrology, component failure analyses, chemical analyses, material properties determination, and electronic equipment and dosimetry calibration. The Supervisor will have as additional responsibility developing and enforcing safety regulations and procedures for the protection of personnel against radioactive hazards.

Computer Services Supervisor

The computer services, supervised by a computer scientist, will provide automated data reduction and analysis services to the testing laboratory. The Supervisor will be assisted by a second computer scientist and a technician.

10.1.4 Assistant Director - Administration

All laboratory administrative personnel will report to the Assistant Director for Administration, whose position will encompass the following functions:

Cost and Budget Manager

The Cost and Budget Manager will be responsible for all accounting functions. All laboratory costs for salaries, materials, supplies and services will be tabulated and monitored by this department. The cost projections will form the basis fo~ year-to-year budgeting. Cost inputs will be developed by this department and gathered from each of the three assistant directors' sections for coding and tabulation on a centralized, biweekly computer printout.

Personnel Manager

The personnel manager will be responsible for maintaining adequate staff level and handling all personnel needs, including benefits, specific problems, special equipment and clothing, and the dispensary. The nurse staffing the dispensary will report directly to the Personnel Manager.

Contracts Officer

The Contracts Officer will be responsible for all agreements with specimen suppliers, service subcontractors, and inter-government agencies.

Publications Manager

Since the end product of the laboratory will be reports describing the performance of safety-system equipment after exposure to specified environments, the Publications Manager will be responsible for report preparation (including typing and art work) and final printing. This department will also print any other in-house documents as necessary.

Purchasing Agent

The Purchasing Agent will perform all purchasing functions, including purchasing raw materials to support the tests and maintain the building, procuring replacement test equipment, and providing all support and office supplies.

Mailroom Supervisor

The Mailroom Supervisor will be responsible for the receipt and distribution of incoming mail and for the timely posting of outgoing mail.

Communications Supervisor

The Communications Supervisor will be responsible for ensuring that external and internal communication lines are in good working order at all times, including teletype, telex and telephone services.

Photographer

The photographer will be responsible for maintenance of the photography and photo-printing equipment and for film development and printing.

Receiving and Storage Supervisor

The storage room will be the central point for the flow of all materials into and out of the laboratory and the various test areas. The Receiving and Storage Supervisor will manage all receiving, packaging and shipping functions.

Clerical/Secretarial Supervisor

All secretarial and clerical personnel will be assigned to functional line groups; however, administratively, they will report to one supervisor. The Clerical/Secretarial Supervisor will be responsible for maintaining a level of assistance consistent with the needs of the laboratory and for handling any minor personnel problems.

10.1.5 Assistant Director - Building and Equipment

The Assistant Director for Building and Equipment will be responsible for the general operation and maintenance of the building. The following personnel will support the Assistant Director:

Building and Services Manager

A manager and maintenance team will attend to the general needs of the building, such as maintenance of heat, steam, electric power and compressed-air equipment; washing and replacing of windows; miscellaneous minor repairs; and grounds maintenance. Outside services will be contracted to provide general cleaning, painting and trash collecting.

Security Manager

Since the laboratory will be a facility with chemical, steam and particularly radiation testing in process, appropriate security will be enforced. A security manager will supervise a team of ten full-time guards, who will maintain 24-hour, 7-day-a-week surveillance of incoming and outgoing personnel and materials, and protection of the grounds.

Machine Shop Supervisor

The machine shop personnel and their supervisor will report to the Building Director, since the machine shop will not only support the various test functions, but will also be available for service equipment and building repairs.

Traffic Supervisor

The Traffic Supervisor will be responsible for ensuring that the flow of goods and personnel into, out of and within the laboratory is smooth, timely and efficient. Assisting the Traffic Supervisor in these tasks will be the Railroad and Truck Freight Manager and the Internal Traffic Manager. Two laboratory vehicles (station wagon type) will transport visitors and run local errands as necessary.

10.1.6 Quality Assurance Manager

The Quality Assurance Manager, with his staff of two engineers and an inspector, will report directly to the Deputy Director and will be responsible for quality assurance (QA). The QA staff will prepare specifications for equipment and raw materials purchased by the laboratory and will check items received for compliance with these specifications. Also, incoming specimens will be checked for conformance with MIL-Q-9858 (Reference 3) and other specifications, as applicable.

10.1.7 Consultants

To provide technical support to the laboratory during its initial startup phase and throughout Phase I, it is recommended that a contract be placed with an independent laboratory experienced in qualification testing of Class 1E equipment to supply expert consulting services. Two full-time consultants will be invaluable for training personnel, establishing test procedures, instructing equipment operators, and providing other guidance with these capabilities, as necessary. As laboratory operator personnel become experienced, the consultant function will be eliminated.

10.1.8 Staff Summary

The number of laboratory staff employees in each job classification is summarized in Table 10-1.

Table 10-1. Laboratory Staff Summary

Classification	No. of Employees
Laboratory Director	1
Deputy Director	1
Assistant Director	3
Manager	7
Supervisor	14
Engineer/Scientist	15
Inspector	1
Technician	22
Draftsperson	2
Nurse	1
Maintenance	6
Guard	10
Secretary	13
Clerk	13
Machinist	4
Helper	8
Vehicle Driver	3
Forklift Operator	2
Switchboard Operator	1
Receptionist	1
	TOTAL 128

10.2 STAFF COSTS

10.2.1 Salaries

An annual budget for salaries of professional and administrative personnel employed by the laboratory is presented in Table 10-2. For convenience, salaries were determined on the basis of GS equivalent grades and salary rates effective October 8, 1978.

A 100% overhead rate was used in computing the annual budget for salaries. (Overhead encompasses items such as employee benefits, travel, education and sick leave.) The total annual cost for employee salaries, including overhead, was estimated as $3,217,712.

10.2.2 Consulting Contract

As mentioned previously, during the startup phase and a subsequent one-year period, a consulting agreement will be entered into with an independent laboratory experienced in qualification testing of Class 1E equipment. This firm will provide technical support to the laboratory. The annual cost of a consulting contract, including two full-time consultants, was estimated as $225,000.

10.3 STAFF FURNISHINGS

The office furniture required for use by the 128 staff personnel is listed in Table 10-3.

Table 10-3. Office Furniture

Office Equipment	Approximate Cost ($)
128 desks	19,200
200 chairs	10,000
500 file cabinets	50,000
30 tables	3,000
50 bookcases	2,500
12 electric typewriters	12,000
3 drawing boards	600
TOTAL	$97,300

Table 10-2. Annual Salaries

Title	Grade	Annual Salary ($)	No. of Employees at Grade	Total Cost per Grade ($)
Laboratory Director	GS-16 Step 3	47,500	1	47,500
Deputy Director	GS-15 Step 1	38,160	1	38,160
Assistant Director	GS-14 Step 1	32,442	3	162,208
Manager	GS-13 Step 1	27,453	7	192,171
Engineer	GS-12 Step 1	23,087	3	69,261
Engineer	GS-11 Step 1	19,263	4	77,052
Engineer	GS-9 Step 1	15,920	4	63,680
Nurse	GS-9 Step 1	15,920	1	15,920
Engineer	GS-7 Step 1	13,014	4	52,056
Supervisor	GS-6 Step 1	11,712	14	163,968
Technician	GS-5 Step 1	10,507	22	231,154
Draftsperson	GS-5 Step 1	10,507	2	21,014
Inspector	GS-5 Step 1	10,507	1	10,507
Secretary	GS-3 Step 1	8,366	13	108,758
Receptionist	GS-3 Step 1	8,366	1	8,366
Switchboard Operator	GS-3 Step 1	8,366	1	8,366
Machinist	GS-3 Step 1	8,366	4	33,464
Vehicle Driver	GS-3 Step 1	8,366	3	25,098
Forklift Operator	GS-3 Step 1	8,366	2	16,732
Maintenance	GS-2 Step 1	7,422	6	44,532
Guard	GS-2 Step 1	7,422	10	74,220
Helper	GS-2 Step 1	7,422	8	59,376
Clerk	GS-1 Step 1	6,561	13	85,293
		Total	127	$1,608,856

11. OPERATING COSTS

11.1 GENERAL

The initial purpose of the laboratory will be to conduct qualification test programs. Typical tasks performed in a qualification program will include:

- Planning, including preparation of checklists;
- Pretest preparation, including fabrication of test fixtures, wiring of energizing and monitoring circuits, and preparation of chemical solutions;
- Conducting tests;
- Analysis of test results; and
- Preparation of test reports.

This section delineates the estimated costs for services and materials, excluding salaries, for a typical operating year of the initial four-year period during which the laboratory will be operating at full capacity to process the 135 test specimens. Approximately seventy-five percent of the operating costs incurred during this period will be attributable to the operation and maintenance of the test equipment. The largest single expense in this initial period of operation will be the maintenance of the radioactive sources. Unless otherwise indicated, the cost of equipment and supplies was based on quotations received by telephone from manufacturers and suppliers.

Detailed cost breakdowns for recurring operating costs are also included in this section.

11.2 RAW MATERIALS

An annual budget for raw materials, which will be purchased for building repairs and for maintenance and modification of test facilities, is discussed in the following paragraphs.

11.2.1 Metals

An annual budget of $20,000 was allocated for the purchase of metals. The following amounts of copper, steel and aluminum were estimated for use on an annual basis:

Type of Metal	Weight (lb)
Steel and iron (plate, pipes, fittings and structural shapes)	5,000
Copper (bars, tubing, fittings and non-insulated wire)	3,000
Aluminum (tubing, sheets and structural shapes)	2,000
Stainless steel (tubing, fittings, sheets and structural shapes)	5,000
Special alloys (e.g., Monel)	500

11.2.2 Wood

An annual budget of $5,000 was allocated for the purchase of wood materials such as boards and plywood sheets.

11.3 SUPPLIES

11.3.1 Building Supplies

An annual budget of $25,000 was allocated for the purchase of electrical supplies for the building and test laboratory, including such items as insulated wire and cable, circuit breakers, fuses, switch boxes, conduit tubing and fixtures, and light bulbs.

An annual budget of $25,000 was allocated for the purchase of additional supplies, in accordance with the following breakdown:

Plumbing supplies	$10,000
Cleaning supplies	$10,000
Paint supplies	$5,000

11.3.2 Laboratory Supplies

An annual budget of $6,000 was allocated for the purchase of chemicals. The following amounts of chemicals were estimated for use during the twelve HELB tests expected to occur in one year:

Type of Chemical	Weight (lb)
Boric acid	7,200
Anhydrous trisodium phosphate	7,200
Hydrazine	11
Sodium hydroxide	1,000
Sodium thiosulfate	1,000

Nitrogen will be used to cycle certain equipment, such as solenoid valves, during HELB tests. An annual budget of $1,500 was allocated for the purchase of nitrogen, based on an estimated annual use of 30 bottles at a cost of $50 per bottle.

11.3.3 Office Supplies

An annual budget of $20,000 was allocated for general office supplies, such as paper, pens, pencils, staplers, typewriter ribbons, etc.

11.4 SERVICES

11.4.1 Heating (Fuel Oil)

The cost of heating the facility for one year was based on the use of oil at an average cost of $0.20/ft^2$ per year. Therefore, the annual cost of heating a 51,000-sq-ft building was estimated as $10,300.

11.4.2 Electricity

The cost of supplying the facility with electricity, including operation of the air-conditioning system and the demand charge of equipment under test, was calculated assuming primary (13.2 kV) electric service. An average annual usage of 3,800,000 kWh, at a rate of $0.04 per kWh, will therefore cost $152,000. This estimate was based on electrical usage by a laboratory currently engaged in qualification testing.

11.4.3 Telephone

The telephone service will consist of a small central switchboard with 100 extensions. Based upon information obtained from the Bell Telephone Company, the estimated cost of telephone service includes a one-time installation charge of $3,500, an average annual equipment rental charge of $18,000, and an annual use charge of $42,000, for a total annual cost of $63,500.

11.4.4 Mailing

A postage meter will be rented from the Post Office at an annual rental charge of $1,000. Annual postage costs were estimated as $24,000, based on costs incurred by an existing laboratory.

11.4.5 Shipping

Depending on the circumstances, either the laboratory or the equipment manufacturer will assume responsibility for the cost involved in shipping test specimens to the laboratory. Annual shipping charges were estimated as $100,000.

11.4.6 Cleaning

The annual cost of a cleaning service contract, including 5-day-a-week cleaning service, was estimated as $25,000.

11.5 MAINTENANCE

11.5.1 Heating, Ventilation and Air-Conditioning (HVAC) Maintenance

The annual cost of maintaining the HVAC system was estimated as $40,000, or approximately 8.5% of the $470,000 purchase price.

11.5.2 Replacement Equipment

An annual budget of $10,000 was allocated for replacement parts for building systems, such as the heating, ventilation and air-conditioning system, air filters, fan belts, nuts and bolts, etc.

11.6 COPYING MACHINES

The purchase of two Xerox 3400® or similar copying machines with collators is recommended. Based upon information supplied by Xerox Company, the purchase cost is $12,825 per machine, which can be financed over five years at 7% interest. Payments would be $228.25/month per machine for principal and interest; a service contract would cost $171.75/month per machine. The rental cost is based upon an average of 10,800 copies per month. Accordingly, the estimated annual cost for both machines is:

	Approximate Annual Cost ($)
Two basic machines	5,478
Two service contracts	4,122
Total	$9,600

11.7 RADIATION SOURCE

The annual cost of maintaining six cobalt-60 sources, at a strength of 0.5×10^6 Curies each, was estimated as $0.25/Curie, or $750,000.

12. SCHEDULE AND COST SUMMARY FOR PHASE I

12.1 CAPITAL INVESTMENT

The capital investment necessary for the design, construction and equipping of a qualification laboratory that meets the requirements of the sequential mode of operation defined for Phase I was estimated as $8,655,000. The time needed to produce the fully-equipped laboratory, ready for checkout, was estimated as four years. The capital costs are detailed in Table 12-1, which summarizes data presented in Sections 4 through 9. To the design, construction and equipping costs must be added the costs of the six-month checkout period needed to bring the laboratory to operational status.

Checkout costs are detailed in the first column of cost data in Table 12-2, where the total estimated checkout cost is shown to be $2,248,000. Checkout costs are based on data presented in Sections 10 and 11 of this report. During the checkout period, costs incurred through use of the test facility will be smaller than those expected during full-scale operation.

The total estimated capital investment is $10,903,000, and the total time to reach operational status is four and one-half years.

12.2 OPERATING COSTS

Operating costs for the five and one-half years following the construction/checkout stage are summarized in Table 12-2. Four years are scheduled for completion of qualification tests on the entire backlog of Class 1E specimens; during the last year and a half, the testing effort will be decreased gradually, and research and development work will be undertaken.

Table 12-1. Phase I Capital Costs for Design, Construction and Equipping of Laboratory

Item	Approximate Cost ($1000)
I. Specifications	
Building	300
Test Equipment	450
II. Building Construction Costs	
Building	3,390
III. Test Facilities Equipment	
Thermal Aging Facility	
Oven (3 ft by 3 ft by 4 ft high)	4
Oven (6 ft by 6 ft by 10 ft high)	20
Vibration Facility	
Two vibration tables	11
Two exciter controls	25
Reinforced foundation and isolation mount	15
Irradiation Facility	
Two hot cells	850
Six cobalt-60 sources	1,500
One 30-ton crane with 20-ft span	51
HELB Facility	
Two pressure vessels	54
Steam generator	48
Steam superheater	90
Structural Test Facility	
Steel I-beams	10
Electrical Test Area	
Water immersion tank	5
Dielectric strength test set	15
Schering bridge	15

Table 12-1. Phase I Capital Costs for Design, Construction and Equipping of Laboratory (continued)

Item	Approximate Cost ($1000)
Test Control and Data Acquisition Center	
Instrumentation	68
Computer (comp. to CDC Cyber 171)	1,000
Special Handling Equipment	
One 10-ton crane with 20-ft span	29
One 30-ton crane with 45-ft span	60
Support Laboratory	300
Machine Shop	134
IV. Service Facilities Equipment	
Mailroom	4
Receiving/shipping	4
Photography laboratory	13
Publications and print shop	47
Building services	20
Dispensary	3
Cafeteria	23
V. Office Furnishings	97
	Total $8,655

Table 12-2. Checkout and Operating Budgets for Phase I

Item	Cap. Costs	← Operating Costs →					
	Checkout	Testing of Specimen Backlog (4 Years)				Follow-on (1-1/2 Yrs)	
	First Six Months	Second Six Months	Second Year	Third Year	Fourth Year	Fifth Year	Sixth Year
Staff Costs							
Salaries	1,609	1,609	3,540	3,894	4,283	4,711	5,183
Consultants	112	113	75	40	40	40	40
Raw Materials							
Metals	10	10	22	24	27	15	16
Wood	2	3	6	7	8	4	4
Building Supplies							
Electrical	10	15	28	30	33	36	40
Plumbing, cleaning, and paint supplies	10	15	27	30	33	37	40
Laboratory Supplies							
Chemicals	3	3	7	8	4	5	6
Nitrogen	1	–	1	1	2	1	1
Office Supplies	5	10	22	24	27	29	32
Services							
Heating (Fuel Oil)	5	5	12	13	14	15	17
Electricity	38	76	167	184	202	167	184
Telephone	21	30	66	73	80	98	97
Mailing	6	13	28	30	33	37	40
Shipping	–	50	110	121	133	73	81
Cleaning	12	13	27	30	33	37	40
Maintenance							
HVAC maintenance	20	20	44	48	53	59	64
Replacement equip.	5	5	11	12	13	14	16
Copying Machines*	4	5	11	12	13	11	9
Radiation Source	375	375	825	908	1,000	1,100	1,210
Total	2,248	2,370	5,029†	5,489†	6,031†	6,489†	7,120†

Notes: * Cost includes purchase price amortized over five years.
† Cost reflects a 10% increase over the previous year to account for inflation.

The operating costs for the four-year period during which the laboratory will be testing the backlog of Class 1E specimens are based on data presented in Section 11 of this report. These and the operating costs associated with the one and one-half years following the four-year testing period, during which the laboratory will begin to undertake research and development, are listed in Table 12-2.

12.3 SCHEDULE AND FUNDING SUMMARY

The schedule for construction and checkout of the proposed laboratory building and operation through five and one-half years is presented in Table 12-3. A summary of the funding required to support this program is shown in Table 12-4.

There are three major milestones in the ten-year schedule: completion of the design, construction and checkout; completion of the testing of the backlog of specimens; and the follow-on one and one-half year period of research and development effort, during which the testing effort will be decreased.

The start-up tasks (Tasks 1 through 9 in Table 12-3) include the preparation of procurement specifications and the design, construction, equipping, staffing and checkout of the facility. These tasks will take four and one-half years to complete and will require a total capital expenditure of $10,903,000.

The backlog of Class 1E equipment is scheduled to be tested within a period of four years with a total operating budget of $22,163,000 for the entire period.

Operating costs for the one and one-half year period during which the testing effort will be diminished and research and development related to safety-system equipment qualification will be built up were estimated as $10,365,000.

Table 12-3. Phase I Schedule

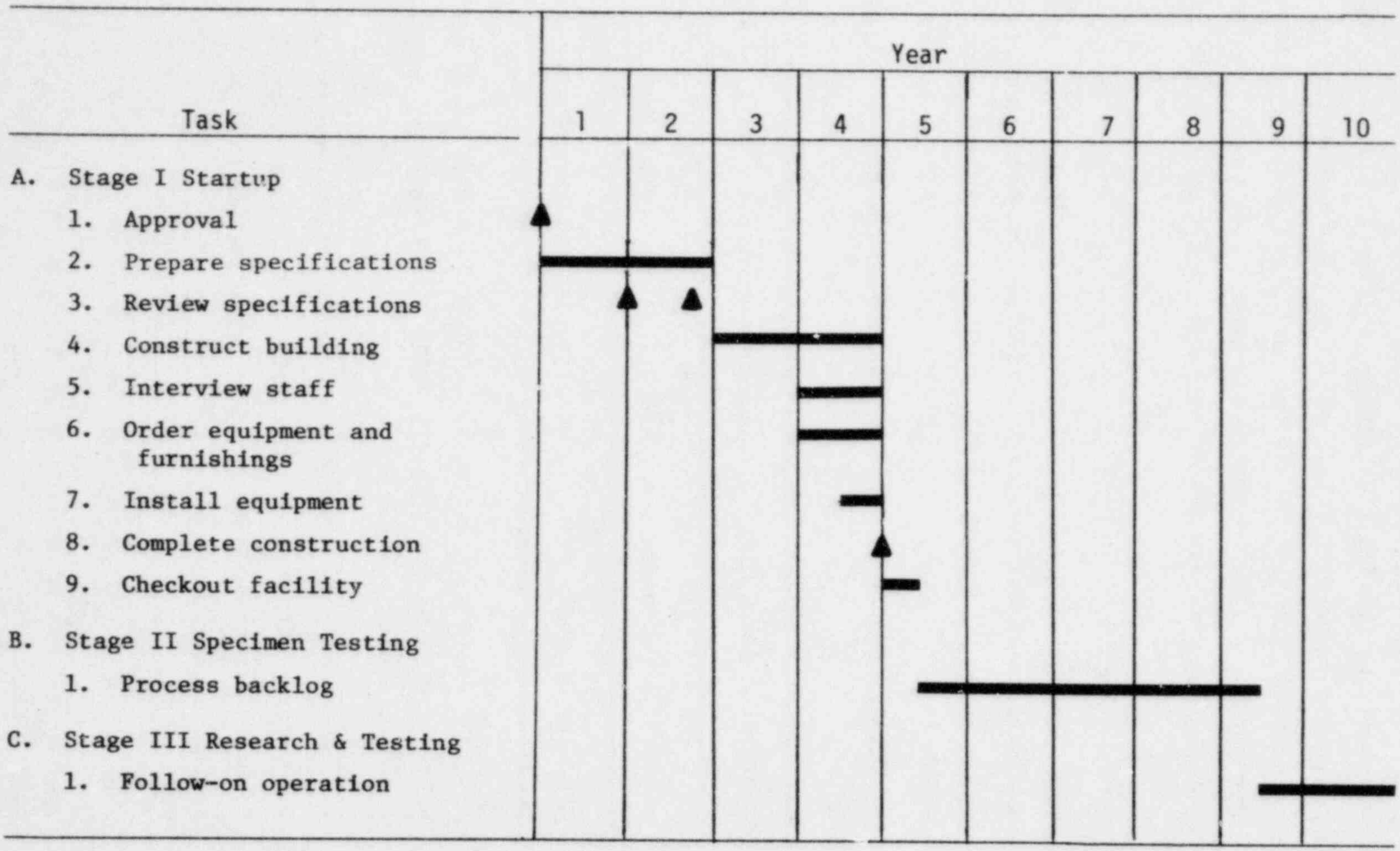


Table 12-4. Summary of Phase I Funding

	COSTS ($1000)										
	Capital					Operating					
TASK / YEAR	1	2	3	4	5	5	6	7	8	9	10
A. STAGE I											
1. Prepare Procurement Specifications	375	375									
2. Construct Building			1695	1695							
3. Equip Building				4515							
4. Facility Checkout					2248						
B. STAGE II											
1. Full-Scale Operation (Process Backlog)						2370	5029	5489	6031	3244	
C. STAGE III											
1. Follow-On Operations										3245	7120

13. PHASE II - LABORATORY FOR PARALLEL-MODE OPERATION

13.1 GENERAL GUIDELINES

The basic objective of the Phase II analysis was to decrease the time required to complete the testing of the entire backlog of 135 Class 1E specimens. An outcome of the Phase I analysis of a minimally equipped laboratory was that four years would be required to test the backlog of specimens in an essentially *sequential* mode. Based on this outcome and considerations of practical limits on the size of a qualification laboratory and the staff that can be recruited, it was decided that the Phase II laboratory should be equipped to process the backlog of specimens within one and one-half years. This was to be accomplished by equipping the laboratory with multiple units of each type of test facility and processing the specimens in a *parallel* mode, as described in Section 1 of this report.

The Phase II testing period of one and one-half years was considered to be a practical limit to which the four-year period of Phase I could be reduced. Further reduction would aggravate the problem of recruiting a qualified staff and putting the laboratory into operation fast enough to meet the specified schedule. It would also severely complicate the logistics of bringing the specimens into the laboratory and processing them on schedule, and any deviation from the schedule would have more critical consequences.

The results of the Phase II analysis are presented in the following subsections, the headings of which correspond to those of Sections 3 through 12, in which the results of the Phase I analysis are presented.

13.2 OPERATING PROCEDURES

The operating procedures for Phase II are similar to those for Phase I, with the exception that a larger number of specimens must be in process at any one time. As in Phase I, the specimens to be tested are those listed in Table 2-1, and the test sequence for each specimen is the same as that discussed in Section 3 and illustrated by Figure 9-1 in Section 9. The test facilities will be the same as those described in Section 4, but more units of each type will be required. As in Phase I, the 135 specimens are separated into 27 groups that will be tested in a large HELB test vessel and 14 groups that will be tested in a small HELB test vessel.

A review of the test durations given in Table 9-1 shows that a minimum of 21.5 weeks will be required to complete all elements of the test program exclusive of the HELB simulation; these include initial inspection and functional testing, thermal aging, irradiation, vibrational aging, operational aging and post-HELB functional tests. Subtracting 21.5 weeks from the 78 weeks in one and one-half years leaves 56.5 weeks, or slightly more than one year, in which all HELB tests are to be completed. Considering that there is a greater demand on the large HELB test vessels, in which 27 groups of specimens will be tested, and that a HELB test is scheduled to take 6 weeks to run, it follows that at least three large HELB test vessels are required (i.e., 27 x 6/56.5 = 2.9). However, to allow for maintenance and repair and other potential interruptions of the smooth flow of specimens through the testing program, it was decided that four large HELB test vessels should be provided. A similar analysis led to the conclusion that at least two small HELB test vessels are required to process 14 groups of specimens within 56.5 weeks (i.e., 14 x 6/56.5 = 1.5). As with the large vessels, to allow for interruptions of the ideal test schedule, it was decided to include four small HELB test vessels in the Phase II laboratory. While this decision provides a possibly generous safety factor with respect to potential delays compared to the safety factor provided by the choice of four large vessels, it would not affect overall costs significantly to choose a smaller number.

13.3 TEST FACILITY REQUIREMENTS

The test equipment necessary to support the Phase II operation is identical to that specified for Phase I, which is described in Section 4.2 of this report, and is listed in Table 13-1. The number of sets of thermal aging ovens, vibration tables, HELB test vessels, and structural and electrical test facilities was quadrupled to support Phase II operations. Since superheated steam is required only for the first one-half hour of the 30-day HELB exposure, two superheaters are adequate for supplying superheated steam to the eight HELB vessels. The two hot cells provided in the gamma irradiation facility of Phase I will suffice for Phase II.

The cranes for handling large equipment are identical to those described in Phase I.

The amount of instrumentation and control equipment was increased in proportion to the increase in the number of each type of test faci[illegible]. A list of control and data acquisition instruments for Phase II is presented in Table 13-2.

The computer will be comparable to a CDC Cyber 171, as planned in Phase I.

13.4 SUPPORT LABORATORIES AND MACHINE SHOP

The same support laboratories and machine shop will be provided for Phase II as those described in Section 5 for the Phase I program. However, the laboratories will be equipped with more scientific apparatus to meet the requirements of the greater work load anticipated for Phase II. Typical support laboratory equipment is listed in Table 5-1, and the amount budgeted for its acquisition for Phase II operations was $325,000. The tools listed in Table 5-2 for equipping the machine shop in Phase I are adequate for Phase II also.

Table 13-1. Phase II Test Facilities

Function	Facility	Est. Floor Space Req'd (ft^2)	Est. Cost ($)
1. Thermal aging	Four 3-ft by 3-ft by 4-ft-high ovens	400	16,800
	Four 6-ft by 6-ft by 10-ft-high ovens	800	80,000
2. Vibrational aging	Four 8-in-diam vibration tables	200	2,000
	Four 6-ft by 10-ft vibration tables	400	40,000
	Eight exciter controls	N/A	98,000
3. Gamma irradiation	Two hot cells	3,600	850,000
	Six cobalt-60 sources	N/A	1,500,000
	One 30-ton crane with 20-ft span	N/A	50,500 (installed)
4. HELB exposure	Four 3-ft-diam by 4-ft-high pressure vessels	800	72,000
	Four 6-ft-diam by 10-ft-high pressure vessels	1,600	144,000
	One 200-bhp steam generator	250	47,500
	Two 200-kW steam superheaters	200	180,000
5. Structural tests (force tests)	Four steel I-beams ("strong-back")	800	40,000
6. Electrical tests (functional tests, operational aging, and cable electrical property tests)	High-voltage power supply	200	N/A
	Low-voltage power supply	200	N/A
	Four water immersion tanks	2,000	20,000
	Four dielectric strength tests	400	60,000
	Four Schering bridges	400	60,000
7. Test control and data acquisition center	See Table 13-2	4,000	231,000
	Computer (comparable to a CDC Cyber 171)	500	1,000,000
8. Special handling equipment	One 10-ton crane with 20-ft span	N/A	29,000 (installed)
	One 30-ton crane with 45-ft span	N/A	59,500 (installed)
		Total	4,580,300

Table 13-2. Phase II Test Control and Data Acquisition Instruments

Quantity	Equipment Type	Approx. Cost
8	ph Meters	$ 6,000
8	Chemical-spray flowmeters	1,600
8	Chemical-solution pumps	2,000
4	Control valves	40,000
24	Two-pen millivolt/temperature recorders	60,000
2	Temperature/pressure recorders	40,000
8	Pressure transducers	4,800
8	Temperature transducers	4,800
8	Pressure gages	2,400
8	Voltmeters (0-750 V ac)	400
8	Multi-amp AC ammeters (10-10,000 mA ac)	4,000
8	Multipoint temperature recorders (24 points, 0-400°F)	24,000
4	Multimeters (1000 V ac dc, 0-20 Ω)	400
4	Megohmmeters (50 kΩ to 5 TΩ, 10-1000 V dc)	4,000
8	Test consoles, including:	
	64 Current meters (5 A movements, use with transformers)	2,600
	64 Current transformers (meter type)	1,000
	8 Potential meters	400
	64 Auto transformers (0-140 V @ 10 A)	2,600
	64 Current (load) transformers (Pri 120 V, Sec 24 V @ 1.5 kVA)	14,000
	24 High-pot transformers (Pri 240 V, Sec 600 V @ 1 kVA)	2,400
	8 (3ϕ stack) auto transformers (Pri 208 V, Sec 280 V @ 4 A)	1,000
	8 Switch panels	1,600
	8 Cabinets (console)	2,800
8	Vibration monitors	4,800
8	Accelerometers	3,200
	Total	$230,800

13.5 SERVICE FACILITIES

The facilities for providing functional services, such as communications and printing, are identical in Phase II to those described for Phase I. The equipment and associated costs are listed in Table 6-1.

13.6 BUILDING REQUIREMENTS

13.6.1 General

The laboratory building designed for Phase II operations will be a single-level structure constructed of concrete and brick with a high-bay ceiling over the test laboratory.

The facility will have 160,000 sq ft of floor space, of which 52,400 sq ft will be allotted for office space, 104,000 sq ft for the test laboratory, and 3,600 sq ft for the irradiation facility. The building layout is illustrated in Figure 13-1, and the principal areas are described in the following subsections.

13.6.2 Test Laboratory

The floor space of the test laboratory designed for Phase II operations will be four times that of the Phase I laboratory to accommodate the fourfold increase in the number of test facilities.

The test laboratory was designed so that similar test facilities are located in one area (e.g., all HELB test vessels will be located adjacent to each other, as illustrated in Figure 13-1). Test areas will be arranged in a sequential pattern consistent with the test sequence proposed in Section 3.

13.6.3 Irradiation Facility

The Phase II irradiation facility, consisting of two hot cells, will be identical to that described in Section 7.1.2 for Phase I, which is of adequate size to meet the requirements of the parallel mode of operation. (The facility is somewhat more than adequate for the Phase I

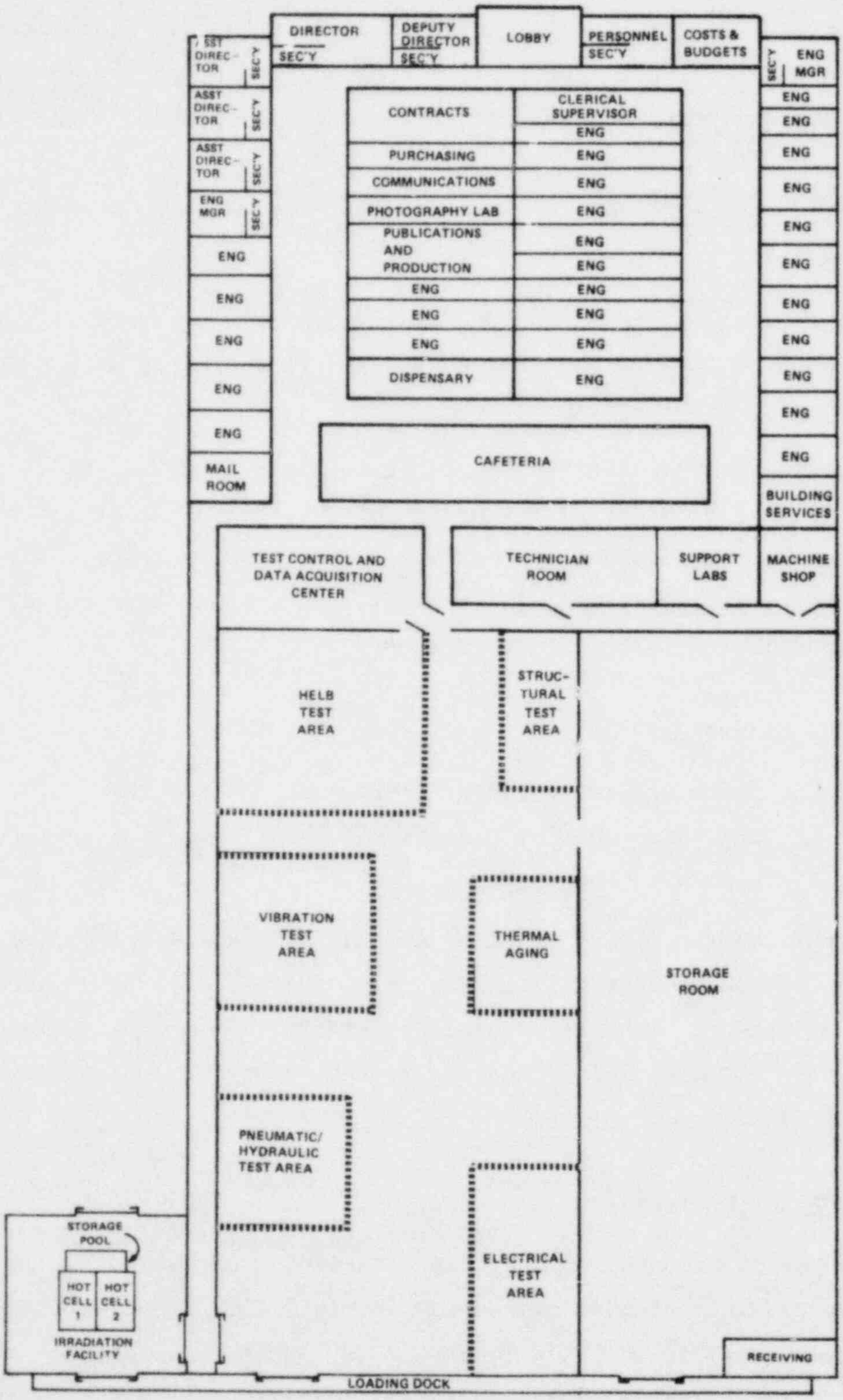


Figure 13-1. Layout of Phase II Qualification Laboratory

sequential mode of operation, in which it does not require continuous utilization.) Each hot cell will be capable of accommodating large test specimens (e.g., two 400-hp motors) or a number of smaller specimens.

13.6.4 Offices

Administrative and Engineering Offices

A total of 46 offices was planned to accommodate 245 administrative and technical employees, as illustrated in Figure 13-1. The design of the office area is similar to that discussed in Section 7.1.3 for Phase I. The administrative and engineering offices will be located at the front of the building, arranged around two corridors.

Cafeteria

The cafeteria will occupy a 10,000-sq-ft area between the offices and the support laboratories and machine shop.

Support Laboratories

The support laboratories, machine shop and technicians' room will be located between the cafeteria and the test laboratory. The area of the technicians' room will be four times that allotted for test personnel in Phase I. It was not considered necessary to allocate additional space for the support laboratories and machine shop for Phase II operations.

13.7 CONSTRUCTION COSTS

The total cost of constructing the proposed 160,000-sq-ft laboratory building, including the test laboratory, irradiation facility (minus the hot cells) and offices, was estimated as $9,600,000. This cost was based on the $60/ft^2 figure obtained from the 1978 Dodge Construction Systems Costs (Reference 2), as discussed in Section 7.2.

13.8 TASKS TO PLAN, BUILD AND INITIATE OPERATION OF THE LABORATORY

The tasks to plan, build and check out the laboratory for Phase II operations are identical to those discussed for Phase I in Section 8. It was not considered feasible to reduce the four and one-half years scheduled for planning, construction and checkout of the laboratory. While a modest reduction might be achieved under extraordinary circumstances, it was not consistent with Phase II guidelines to assume extraordinary conditions.

13.9 STAFFING REQUIREMENTS

13.9.1 Organization

An organization chart and staffing level for the Phase II laboratory are presented in Figure 13-2.

The management organization of the Laboratory for Phase II operations is identical to that planned for Phase I, and the responsibilities and functions of the directors and managers are identical to those described for Phase I in Section 10. There will be no increase in the number of management personnel. However, Phase II operations will require an increase in the engineering and technical staff proposed for Phase I to support the additional test work load. The number of employees proposed for each labor category is summarized in Table 13-3.

13.9.2 Staff Costs

Salaries

The projected expenditure for salaries, which were based on GS equivalent grades and salaries effective October 8, 1978, is tabulated in Table 13-4. Including an overhead rate of 100% as in Phase I, the total annual cost for staff was estimated as $5,845,630.

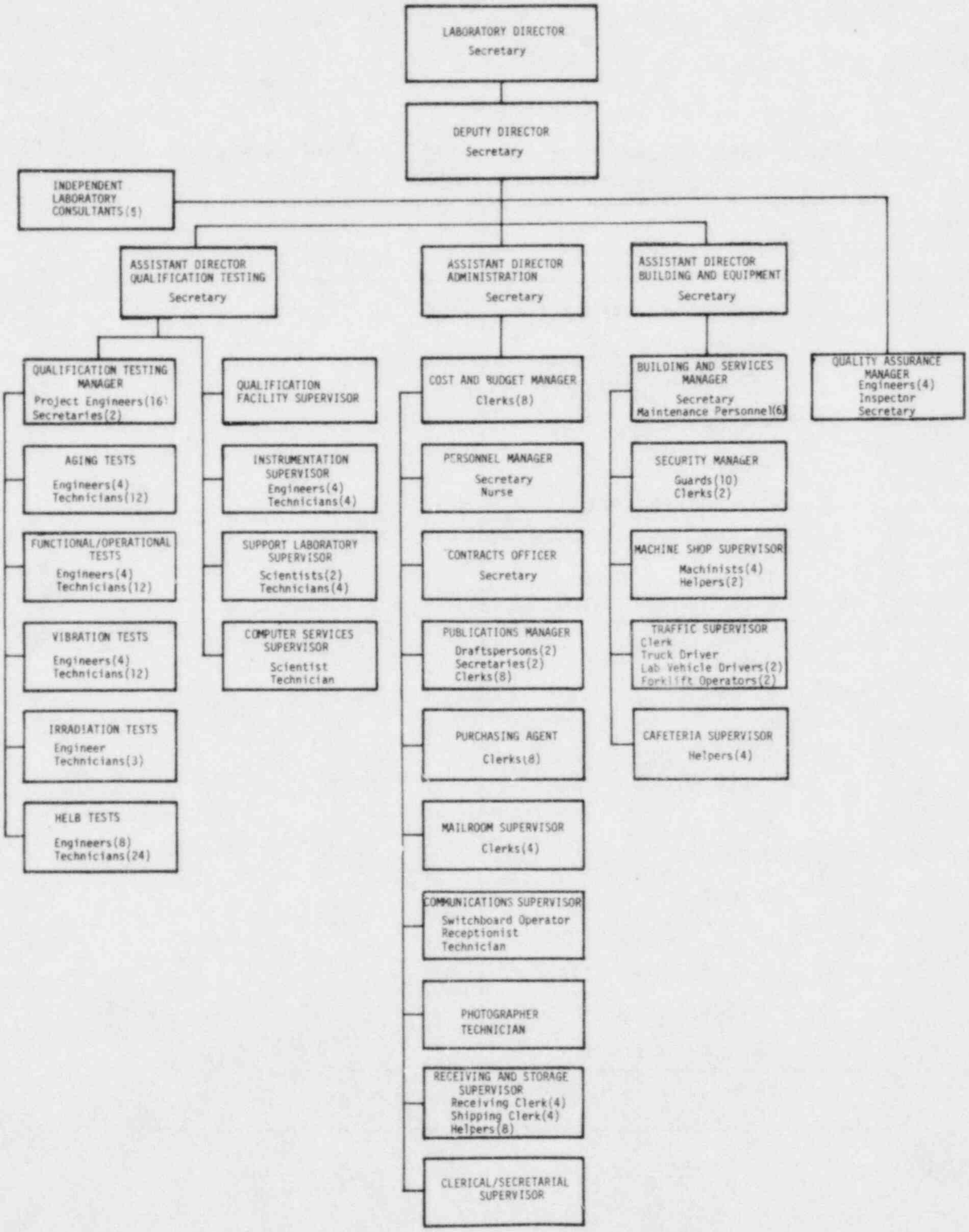


Figure 13-2. Organization Chart and Staffing Level for Phase II Qualification Laboratory

Table 13-3. Summary of Personnel Required to Staff the Laboratory for Phase II Operations

Classification	No. of Employees
Laboratory Director	1
Deputy Director	1
Assistant Director	3
Manager	7
Supervisor	14
Engineer/Scientist	48
Inspector	1
Technician	74
Draftsperson	2
Nurse	1
Maintenance	6
Guard	10
Secretary	13
Clerk	39
Machinist	4
Helper	14
Vehicle Driver	3
Forklift Operator	2
Switchboard Operator	1
Receptionist	1
Total	245

Table 13-4. Phase II Annual Salaries

Title	Grade	Annual Salary ($)	No. of Employees at Grade	Total Cost Per Grade ($)
Director	GS-16 Step 3	47,500	1	47,500
Deputy Director	GS-15 Step 1	38,160	1	38,160
Assistant Director	GS-14 Step 1	32,442	3	97,326
Manager	GS-13 Step 1	27,453	7	192,171
Engineer	GS-12 Step 1	23,087	12	277,044
Engineer	GS-11 Step 1	19,263	12	231,156
Engineer	GS-9 Step 1	15,920	12	191,040
Nurse	GS-9 Step 1	15,920	1	15,920
Engineer	GS-7 Step 1	13,014	12	156,168
Supervisor	GS-6 Step 1	11,712	14	163,968
Technician	GS-5 Step 1	10,507	74	777,518
Draftsperson	GS-5 Step 1	10,507	2	21,014
Inspector	GS-5 Step 1	10,507	1	10,507
Secretary	GS-3 Step 1	8,366	13	108,758
Receptionist	GS-3 Step 1	8,366	1	8,366
Switchboard Operator	GS-3 Step 1	8,366	1	8,366
Machinist	GS-3 Step 1	8,366	4	33,464
Vehicle Driver	GS-3 Step 1	8,366	3	25,098
Forklift Operator	GS-3 Step 1	8,366	2	16,732
Maintenance	GS-2 Step 1	7,422	6	44,532
Guard	GS-2 Step 1	7,422	10	74,220
Helper	GS-2 Step 1	7,422	14	133,908
Clerk	GS-1 Step 1	6,561	39	249,879
		Total	245	$2,922,815

Consulting Contract

A consulting company experienced in qualification testing will be engaged by the laboratory to provide technical support during the initial period of operation. Four engineering consultants and a supervisor will be placed under contract at a cost of $250,000 per year.

13.9.3 Staff Furnishings

The cost of staff office furnishings for Phase II operations was estimated as $130,100, as shown in Table 13-5.

Table 13-5. Phase II Office Furnishings

Office Equipment	Approximate Cost ($)
250 desks	37,500
400 chairs	20,000
500 file cabinets	50,000
50 tables	5,000
100 bookcases	5,000
12 electric typewriters	12,000
3 drawing boards	600
Total	$130,100

13.10 OPERATING COSTS

13.10.1 General

The initial objective of the laboratory during Phase II operations will be to conduct qualification test programs for the 135 specimens (see Table 2-1) during the first one and one-half years of operation. During this period, the laboratory will be operating at full capacity. Following completion of testing on the backlog of specimens, the laboratory will continue to accept new specimens for qualification testing, but will devote more effort to the development and verification of accelerated aging and testing methods for use in evaluating test methodologies.

The costs associated with the operation of the laboratory at full capacity, broken down by salary, raw materials, and services, are discussed in the following subsections.

The annual operating costs in the years during which the laboratory will operate at less than full capacity will be reduced in some areas (e.g., electrical demand, chemicals for HFLB exposures), as reflected in the summaries of Sections 13.10 and 13.11.

13.10.2 Raw Materials

An annual budget for raw materials used in the fabrication and repair of special test fixtures and for building repairs is discussed in subsequent paragraphs.

Metals

An annual budget of $80,000 was allocated for the purchase of metals. The estimated quantities of copper, steel and aluminum needed on an annual basis are:

Type of Metal	Weight (lb)
Steel and iron (plate, pipes, fittings and structural shapes)	12,000
Copper (bars, tubing, fittings and non-insulated wire)	12,000
Aluminum (tubing, sheet and structural shapes)	2,000
Stainless steel (tubing, fittings, sheets and structural shapes)	10,000
Special alloys (e.g., Monel)	2,000

Wood

An annual budget of $20,000 was allocated for the purchase of wood materials such as boards and plywood sheets.

13.10.3 Supplies

Building Supplies

An annual budget of $70,000 was allocated for the purchase of electrical supplies.

An annual budget of $70,000 was allocated for the purchase of other supplies, in accordance with the following breakdown:

Plumbing supplies	$25,000
Cleaning supplies	25,000
Paint supplies	20,000

Laboratory Supplies

An annual budget of $29,900 was allocated for the purchase of chemicals, based on the following estimate of the amounts necessary for conducting HELB tests over a one-year period:

Ch[illegible]	Weight (lb)		Annual Cost ($)
Boric acid	28,800		7,600
Anhydrous trisodium phosphate	28,800		11,400
Hydrazine	40		3,900
Sodium hydroxide	4,000		4,000
Sodium thiosulfate	4,000		4,000
		Total	$29,900

An annual budget of $4,000 was allocated for the purchase of nitrogen, based on an estimated annual use of 80 bottles at a cost of $50 per bottle.

Office Supplies

An annual budget of $40,000 was allocated for general office supplies such as paper, pencils, scissors, typewriter ribbons, etc.

13.10.4 Services

Heating (Fuel Oil)

The cost of heating the facility for one year with fuel oil was based on the approximate cost of $\$0.20/ft^2$ per year incurred by a similar laboratory. Therefore, the annual cost to heat the proposed 156,400-sq-ft building would be \$31,300.

Electricity

The annual cost of electricity was estimated as \$605,600, based on an annual kilowatt usage by a similar testing facility of 30,278,400 kWh, at a rate of \$0.04/kWh.

Telephone

A telephone service with a central switchboard and 200 extensions is recommended. The cost of this service includes a one-time installation charge of \$7,000, an annual equipment rental charge of \$36,800, and an annual use charge of \$84,000. Therefore, an annual budget of \$127,800 was allocated for telephone service.

Mailing

A postage meter will be rented from the Post Office at an annual charge of \$1,000. In addition, annual postage costs were estimated as \$47,000.

Shipping

Depending on the circumstances, either the laboratory or the equipment manufacturer will assume responsibility for the cost involved in shipping test specimens to the laboratory. An annual budget of \$40,000 was allocated for transportation charges for the shipment of test specimens and equipment.

Cleaning

The annual cost of a cleaning service contract, including 5-day-a-week cleaning service, was estimated as $50,000.

13.10.5 Maintenance

Heating, Ventilation and Air-Conditioning (HVAC) Maintenance

The annual cost of maintaining the HVAC system was estimated as $122,000, or approximately 8.5% of the $1,435,000 purchase price.

Replacement Equipment

An annual budget of $40,000 was allocated for replacement parts for building systems, such as the heating, ventilation and air-conditioning system, air filters, fan belts, nuts and bolts, etc.

13.10.6 Copying Machines

The purchase of two Xerox 3400 copying machines with collators is recommended, as previously discussed in Section 11.6 for Phase I. An annual cost of $9600 was estimated, which includes an annual rental charge of $5478 for the two machines and an annual service contract charge of $4122.

13.10.7 Radiation Source

An annual budget of $750,000 was allocated to maintain the radioactive cobalt-60 sources. This is the same amount budgeted for the Phase I laboratory, because there was no change in source strength for the Phase II laboratory.

13.11 SCHEDULE AND COST SUMMARY FOR PHASE II

13.11.1 Capital Investment

The capital investment necessary for the design, construction and equipping of a qualification laboratory that meets the requirements of the parallel mode of operation defined for Phase II was estimated as $15,686,000. The capital costs are detailed in Table 13-6. The time needed to produce the fully-equipped laboratory, ready for checkout, was estimated as four years.

To the design, construction and equipping costs must be added the costs of the six-month checkout period needed to bring the laboratory to operational status. Checkout costs are detailed in the first column of cost data in Table 13-7, where the total estimated checkout cost is shown to be $3,886,000.

The total estimated capital investment is $19,572,000, and the total time to reach operational status is four and one-half years.

13.11.2 Operating Costs

The operating costs for the three and one-half years following the construction/checkout stage are summarized in Table 13-7. One and one-half years are scheduled for completion of qualification tests on the entire backlog of Class 1E specimens; during the last two years, the testing effort will be decreased gradually, and research and development work will be undertaken.

13.12 SCHEDULE AND FUNDING SUMMARY

The schedule for construction and checkout of the proposed laboratory building and operation through three and one-half years is presented in Table 13-8. A summary of the funding required to support this program is shown in Table 13-9.

There are three major milestones in the eight-year schedule: completion of the design, construction and checkout; completion of the testing of the backlog of specimens; and the follow-on two-year period of research and development during which the testing effort will be decreased.

The start-up tasks (Tasks 1 through 9 in Table 13-8) include the preparation of procurement specifications and the design, construction, equipping, staffing and checkout of the facility. These tasks will take four and one-half years to complete and will require a total capital expenditure of $19,572,000.

The backlog of Class 1E specimens is scheduled to be tested within a period of one and one-half years with a total operating budget of $12,962,000 for the entire period. Operating costs for the two-year period during which the testing effort will be diminished and research and development related to safety-system equipment qualification will be built up, were estimated as $20,325,000.

Table 13-6. Phase II Capital Costs for the Design, Construction and Equipping of Laboratory

Item	Approximate Cost ($1000)
I. Specifications	
Building	300
Test Equipment	450
II. Building Construction Costs	
Building	9,600
III. Test Facilities Equipment	
Eight circulating-air ovens	97
Vibration Facility	
Eight vibration tables	42
Eight exciter controls	98
Reinforced foundation and isolation mount	60
Irradiation Facility	
Two hot cells	850
Six cobalt-60 sources	1,500
One 30-ton crane with 20-ft span	50
HELB Facility	
Eight pressure vessels	216
Steam generator	48
Two steam superheaters	180
Structural Test Facility	
Four steel I-beams	40

Table 13-6. Phase II Capital Costs for the Design, Construction and Equipping of Laboratory (cont.)

Item	Approximate Cost ($1000)
Electrical Test Area	
Four water immersion tanks	20
Four dielectric strength test sets	60
Four Schering bridges	60
Test Control and Data Acquisition Center	
Instrumentation	231
Computer (comp. to CDC Cyber 171)	1,000
Special Handling Equipment	
One 10-ton crane with 20-ft span	29
One 30-ton crane with 45-ft span	60
Support Laboratory	325
Machine Shop	134
IV. Service Facilities Equipment	
Mailroom	4
Receiving/shipping	4
Photography laboratory	13
Publications and print shop	47
Building services	20
Dispensary	3
Cafeteria	14
V. Office Furnishings	131
Total	15,686

Table 13-7. Checkout and Operating Budgets for Phase II

Item	Cap. Costs	Operating Costs			
	Checkout	Testing of Specimen Backlog (1-1/2 yrs)		Follow-on Effort (2 yrs)	
	First Six Months	Second Six Months	Second Year†	Third Year†	Fourth Year†
Staff Costs					
Salaries	2,923	2,923	6,430	7,033	7,780
Consultants	125	125	83	42	42
Raw Materials					
Metals	20	40	88	97	107
Wood	2	10	20	22	24
Building Supplies					
Electrical	10	35	77	85	93
Plumbing, cleaning and paint supplies	35	35	77	85	93
Laboratories Supplies					
Chemicals	2	15	30	33	36
Nitrogen	2	2	4	4	5
Office Supplies	20	20	44	48	53
Services					
Heating (Fuel Oil)	16	16	34	38	42
Electricity	150	300	660	726	800
Telephone	66	66	132	145	160
Mailing	24	24	53	58	64
Shipping	5	20	44	48	53
Cleaning	25	25	55	60	66
Maintenance					
HVAC maintenance	61	61	134	148	163
Replacement equipment	20	20	44	48	53
Copying Machines*	5	5	11	12	13
Radiation Source	375	375	825	908	998
Total	3,886	4,117	8,845	9,680	10,645

*Cost includes purchase price amortized over five years.
†Cost reflects a 10% increase over the previous year to account for inflation.

Table 13-8. Phase II Schedule

Task	Year 1	2	3	4	5	6	7	8
A. Stage I. Startup								
1. Approval								
2. Prepare specifications								
3. Review specifications								
4. Construct building								
5. Interview staff								
6. Order equipment and furnishings								
7. Install equipment								
8. Complete construction								
9. Checkout facility								
B. Stage II. Specimen Testing								
1. Process backlog								
C. Stage III. Research and Testing								
1. Follow-on operation								

Table 13-9. Summary of Phase II Funding

TASK / YEAR	Cost ($1000)								
	Capital					Operating			
TASK / YEAR	1	2	3	4	5	5	6	7	8
A. Stage I									
1. Prepare procurement specifications	375	375							
2. Construct building			1,695	1,695					
3. Equip building				4,515					
4. Facility checkout					3,886				
B. Stage II									
1. Full-scale operation (Process backlog)						4,117	8,845		
C. Stage III									
1. Follow-on operation								9,680	10,645

14. REFERENCES

1. IEEE Std 323-1974, "IEEE Standard for Qualifying Class IE Equipment for Nuclear Power Generating Stations," The Institute of Electrical and Electronics Engineers, Inc., New York, NY, 1974.

2. 1978 Dodge Construction Systems Costs, McGraw-Hill Information Systems, 1977.

3. MIL-Q-9858A, 1962, "Quality Program Requirements," DOD Quality Control Specification.

APPENDIX C

Facilities Capabilities Questionnaire and Responses

Nancy C. Finley
Sandia Laboratories

APPENDIX C

Facilities Capabilities Questionnaire and Responses

The purpose of this survey was to evaluate the currently existing facilities for qualification testing of Class 1E safety-related equipment for nuclear power plants. In developing the questionnaire, two basic types of information were sought.

1. General information relating to the capabilities of an organization.

2. Specific information on a particular type of test.

Development of the questionnaire format was accomplished by surveying the existing regulations to determine what types of tests were required and to assess what information was essential to the evaluation of testing capabilities. The proposed format was then circulated among the staff at Sandia with experience in such testing. This process produced an expansion of the number of tests to be evaluated and the significant questions to be asked.

The selection of organizations to be evaluated was accomplished by requesting input from the Sandia staff, the NRC staff and by examining the trade journals for further information. The resulting list of 120 organizations included 21 government (and related) agencies, 5 academic institutions and the remainder (94) private sector organizations. Each organization was assigned a random three digit number and the questionnaire results are summarized utilizing these numbers. A copy of the survey questionnaire is included in this appendix for reference. A reminder to organizations was sent in November, 1978, to allow for a more complete set of responses.

Initial analysis of the survey data was performed in several different ways. First, the general information with respect to what organizations performed, or were interested in performing, tests for the NRC and the organizations general testing capabilities (i.e., what tests are performed) were summarized. These results are displayed in Tables C-1 to C-3. Specific information on particular testing capabilities was then summarized on a selected organization by organization basis as well as on a test by test basis. For simplification, only the information on a selected organization basis is presented here. That information is summarized in Table C-4 for government agencies, Table C-5 for academic institutions, Table C-6 for manufacturing organizations, and Table C-7 for testing laboratories. These selected organizations represent the bulk of the testing capability in the United States.

Sandia Laboratories

Albuquerque, New Mexico 87115

September 15, 1978

Dear Sir:

Sandia Laboratories is engaged in an investigative program funded by the U.S. Nuclear Regulatory Commission to evaluate the NRC's options in independently verifying the qualification tests of Class 1E components for nuclear power plants. Three options are being evaluated (1) an NRC test facility, (2) subcontracted tests to existing laboratories, and (3) witness of qualification tests by NRC personnel. It is in achieving the second goal of this study that we require your cooperation and assistance.

I have enclosed a questionnaire which should allow us to evaluate existing qualification test capabilities both at your laboratory and others in the United States. Your cooperation in completing and returning it promptly will be greatly appreciated. While the questionnaire is relatively long, its length results from our effort to simplify organization of the results and minimize your work in answering the questions. In addition to the questionnaire, we request that you send two copies of technical capabilities brochures relating to the qualification test facilities covered in the questionnaire.

Data from the questionnaire will be summarized in a report to the NRC which will be used to select one of the three verification options listed above. This report will not include specific information on the capability of individual test facilities. However, the specific information from each respondent will be included in a data package to be submitted to NRC staff for possible future use in assembling a bidders' list for verification tests.

More information on the study can be obtained from:

1. Nancy Finley 505-844-4301
2. L. L. Bonzon 505-844-4313

We would like to receive by October 1, 1978 your reply consisting of:

The completed questionnaire

2 copies of relevant technical capabilities brochures

We have enclosed a self-addressed mailing label for your convenience. I look forward to your prompt response in this matter and thank you in advance for your time and effort in supplying the information.

Very truly yours,

R. E. Luna
Supervisor, Systems Safety
Technology Division 5432

REL:5432:mh

1. Is your organization a:

   1. Testing Division of a manufacturing company ____________________
   2. Testing laboratory ____________________
   3. Government laboratory ____________________
   4. Nonprofit organization ____________________

2. Do you perform qualification testing for the nuclear industry?

   Yes _____ No _____

3. Would you perform qualification testing for the Nuclear Regulatory Commission?

   Yes _____ No _____

4. Would you perform independent qualification testing for the Nuclear Regulatory Commission on equipment similar to that already tested for companies in the private sector?

   Yes _____ No _____

5. Is there another branch of your organization which does qualification testing?

   Yes _____ No _____

   If so, please specify.

Type of Test Procedure	Check tests which you perform.	Check tests you would subcontract. (Indicate to whom on attached sheet)	Check tests which can be performed simultaneously.	Can the equipment being tested be operated during the test?	Are quality assurance practices applied to test procedures and equipment to assure validity of test results and reproducibility? (Please describe on separate sheet provided.)	If operating at full capacity, how may of these tests could you perform in a six month period? (approximately)	What advance notice is needed to schedule use of test equipments?	Indicate those tests you anticipate you will be able to perform by 1980 based on approved plans for upgrading your facilities.	
1. Aging a. Radiation b. Thermal c. Function Cycling									
2. Humidity									
3. Steam Environment a. Saturated steam b. Superheated steam									
4. Pressure									
5. Function a. Mechanical b. Electrical									
6. Chemical Spray									
7. Vibration (not seismic)									
8. Seismic Condition Simulation									
9. Radiation									

Subcontractor Information:

Quality Assurance Practices:

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Complete This Section Only If You Can Perform
AGING Tests (Radiation, Thermal, etc.)

1. Number of aging chambers available.

2. Give the size/volume of the aging chamber(s).

3. Give the size/volume of the chambers for radiation aging over which the flux does not vary over 20%; over 50%.

4. Are there limits on the length of time a particular aging environment can be maintained?

Yes _____ No _____

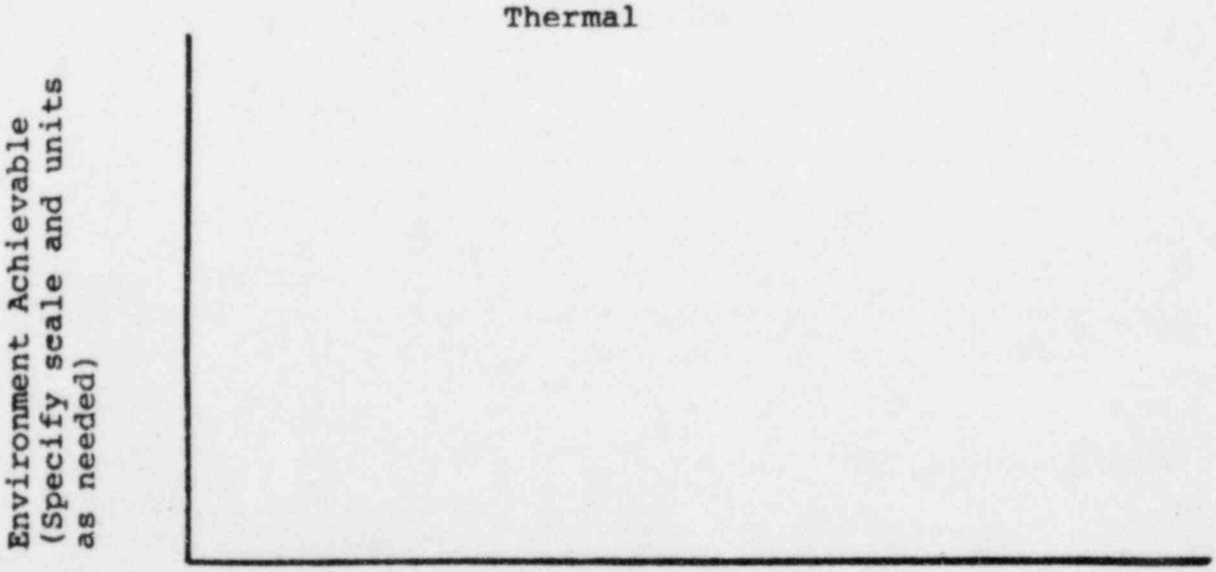
If yes, please indicate limits.

5. What are the rate(s) of application of radiation aging?(years/day)

6. What are the rate(s) of application of thermal aging?(years/day)

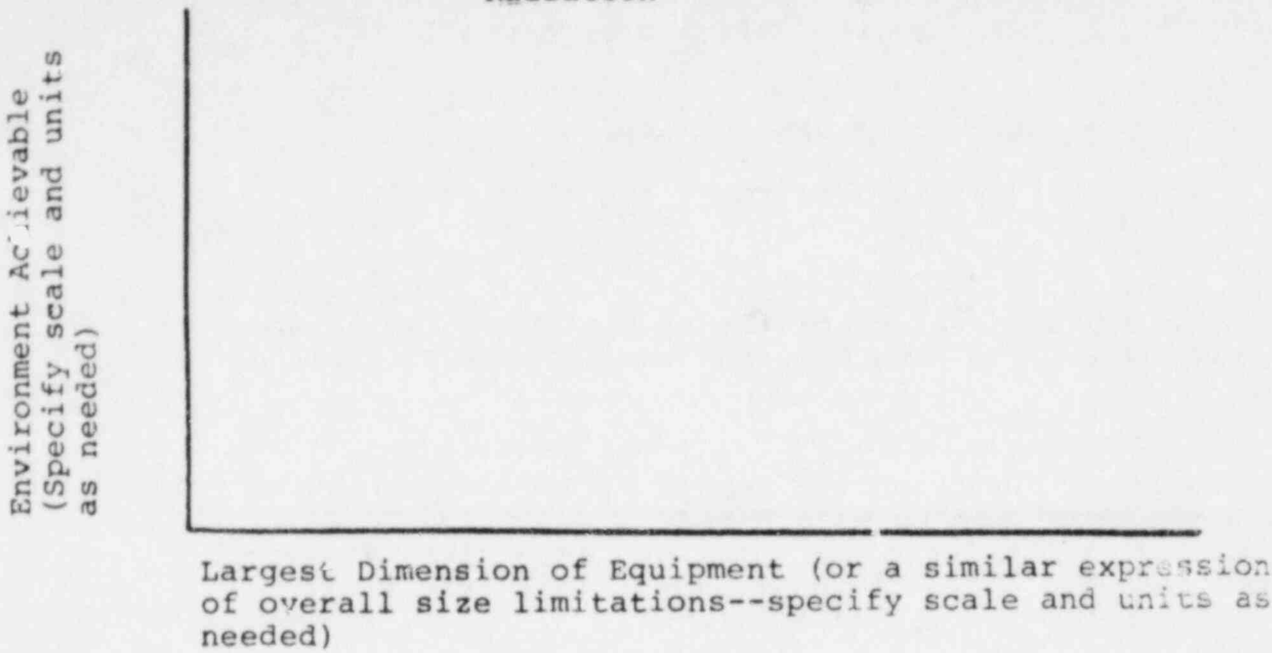
7. Using the axes below, indicate the aging environment achievable (specify scale and units as needed, temperature, dose rate, etc.) as a function of the size of equipment to be tested.

Thermal

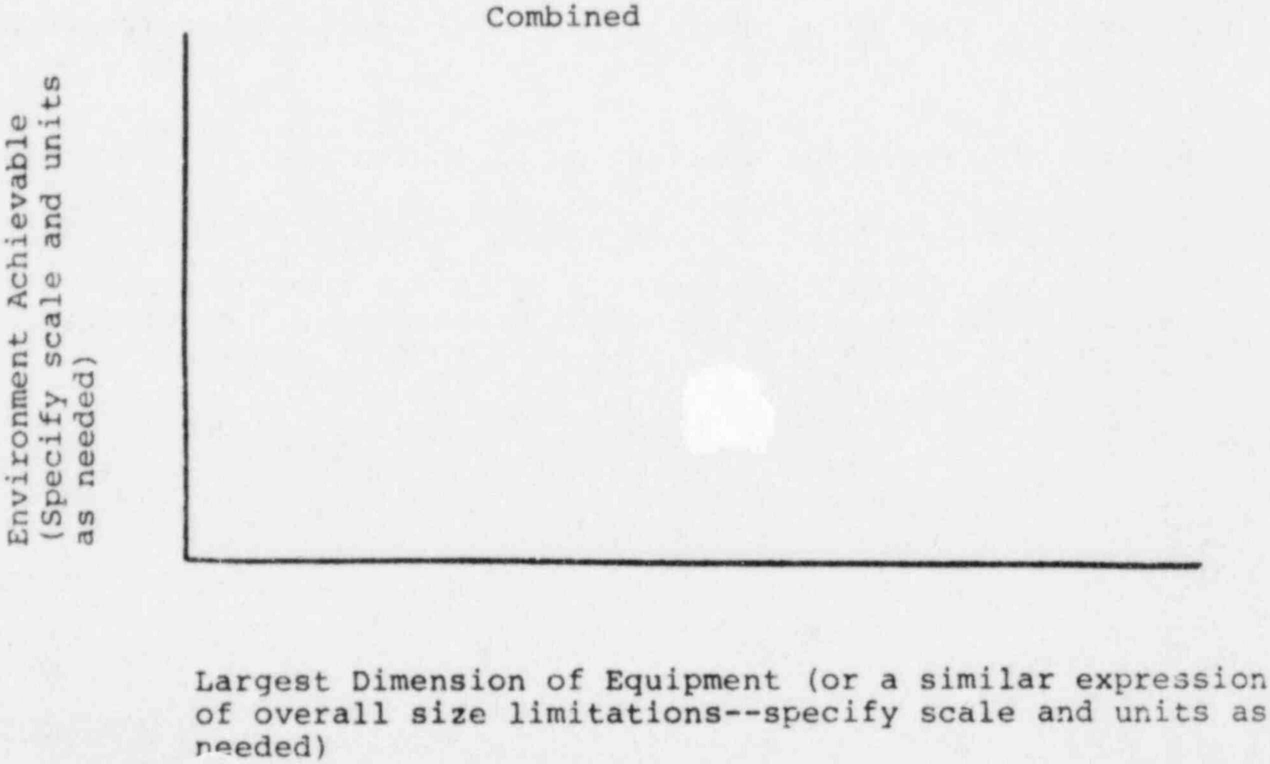


Largest Dimension of Equipment (or a similar expression of overall size limitations--specify scale and units as needed)

Radiation



Combined



8. For radiation aging:

   a. What radiation sources are used?

   b. Can dose rate be actively varied during the test? Yes ___ No ___

1) If yes:

i. How is the variation accomplished?

ii. What is the range over which the dose rate can be varied?

iii. What is the smallest change that can be made?

2) If no, what manual variations can be made on the dose rate?

9. Can the thermal environments be actively varied during the test?

Yes _____ No _____

a. If yes, how is the variation accomplished?

b. If no, what manual variations can be made on the thermal environment?

10. Can the aging process be accomplished in other than air environments?

Yes _____ No _____

If yes, what environments can be accommodated?

11. Where possible, indicate a rough cost estimate per test.

COMMENTS:

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Complete This Section Only If You
Can Perform HUMIDITY Tests

1. Number of humidity chambers available __________.

2. Give the size/volume of the humidity chamber(s).

3. Are there limits on the length of time a particular humidity environment can be maintained?

   Yes _____ No _____

   If yes, please indicate limits.

4. How rapidly can the humidity environment be established?

5. Using the axes below, indicate the humidity environment achievable (specify scale and units) as a function of the size of equipment to be tested.

Environment Achievable (Specify scale and units as needed)

Largest Dimension of Equipment (or a similar expression of overall size limitations--specify scale and units as needed)

6. Can the humidity be actively varied during the test?

Yes _____ No _____

a. If yes:

i. How is the humidity varied?

ii. What is the range over which it can be varied?

iii. What is the smallest change that can be made?

b. If no, what manual variations can be made?

7. Where possible, indicate a rough cost estimate per test.

COMMENTS:

Complete This Section Only If You Can
Perform STEAM ENVIRONMENT Tests

1. Number of steam environment test chambers available _______.

2. Give the size/volume of the test chambers.

3. Are there limits on the length of time:

   a. a superheated steam environment can be maintained?

      Yes _____ No _____

      If yes, please indicate limits.

   b. a saturated steam environment can be maintained?

      Yes _____ No _____

      If yes, please indicate limits.

4. What are the rates of application of the steam environment? (Indicate separate values for superheated steam and saturated steam as applicable.)

5. Using the axes below, indicate steam environment achievable as a function of the size of the equipment to be tested.

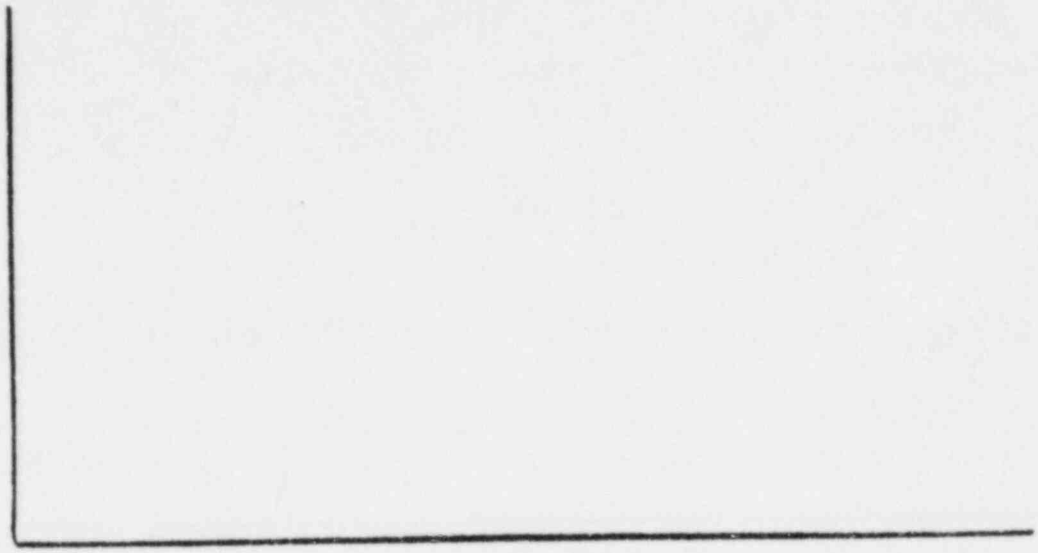
Superheated Steam

Environment Achievable (Specify scale and units as needed)

Largest Dimension of Equipment (or a similar expression of overall size limitations--specify scale and units as needed)

Saturated Steam

Environment Achievable (Specify scale and units as needed)



Largest Dimension of Equipment (or a similar expression of overall size limitations--specify scale and units as needed)

6. Can the steam environment be actively varied during the test?

   Yes _____ No _____

   a. If yes:

      i. How is the environment varied?

      ii. What is the range of steam environments available?

      iii. What is minimum change that can be made?

   b. If no, what manual variations are possible?

7. Where possible, indicate a rough cost estimate per test.

COMMENTS:

Complete This Section Only If You Can
Perform PRESSURE Tests

1. Number of pressure chambers available ______.

2. Give the size/volume of the pressure chamber(s).

3. Are there limits on the length of time the pressure environment can be maintained?

   Yes _____ No _____

   If Yes, please indicate limits.

4. What are the rate(s) of application of the pressure environment?

5. Using the axes below, indicate the pressure environment achievable as a function of the size of the equipment to be tested.

Environment Achievable (Specify scale and units as needed)

Largest Dimension of Equipment (or a similar expression of overall size limitations--specify scale and units as needed)

6. Can the pressure environment be actively varied during the test?

Yes _____ No _____

a. If yes:

i. How is the pressure varied?

ii. What range of pressures can be used?

iii. What is the minimum change that can be made?

b. If no, what manual variations can be made?

7. Where possible, indicate a rough cost estimate per test.

COMMENTS:

Complete This Section Only If You Can Perform FUNCTION Tests (Mechanical and/or Electrical)

1. What mechanical function tests can you perform?

2. What electrical function tests can you perform?

3. Are special chambers used for mechanical and/or electrical function tests?

   Yes _____ No _____

   a. If yes, how many chambers available? _______

   b. Give the size/volume of the chamber(s).

4. Are there limits to the time a mechanical and/or electrical function test can be continued?

   Yes _____ No _____

   If yes, please indicate limits where applicable.

5. What are the rates of application of mechanical and/or electrical function tests?

6. Can the mechanical and/or electrical function(s) be actively varied during the test?

   Yes _____ No _____

   a. If yes:

      i. How are the variations accomplished?

ii. What is the range of values available?

iii. What is the smallest change that can be made?

b. If no, what manual variations can be made?

7. Where possible, give a rough cost estimate per test.

COMMENTS:

Complete This Section Only If You Can
Perform CHEMICAL SPRAY Tests

1. Number of chemical spray test chambers available _______

2. Give size/volume of the test chamber(s).

3. What different chemical spray environments are available?

4. Are there limits to the length of time a chemical spray environment can be maintained?

   Yes _____ No _____

   If yes, please indicate limits.

5. What are the rates of application of the chemical spray environment(s)?

6. Using the axes below, indicate the chemical spray environment achievable as a function of the size of equipment to be tested.

Environment Achievable (Specify scale and units as needed)

Largest Dimension of Equipment (or a similar expression of overall size limitations--specify scale and units as needed)

7. Can the chemical spray be actively varied during the test?

Yes _____ No _____

a. If yes:

i. How is the environment varied?

ii. What range of sprays can be used:

iii. What is the smallest change that can be made:

b. If no, what manual variations can be made?

8. Where possible, indicate a rough cost estimate per test.

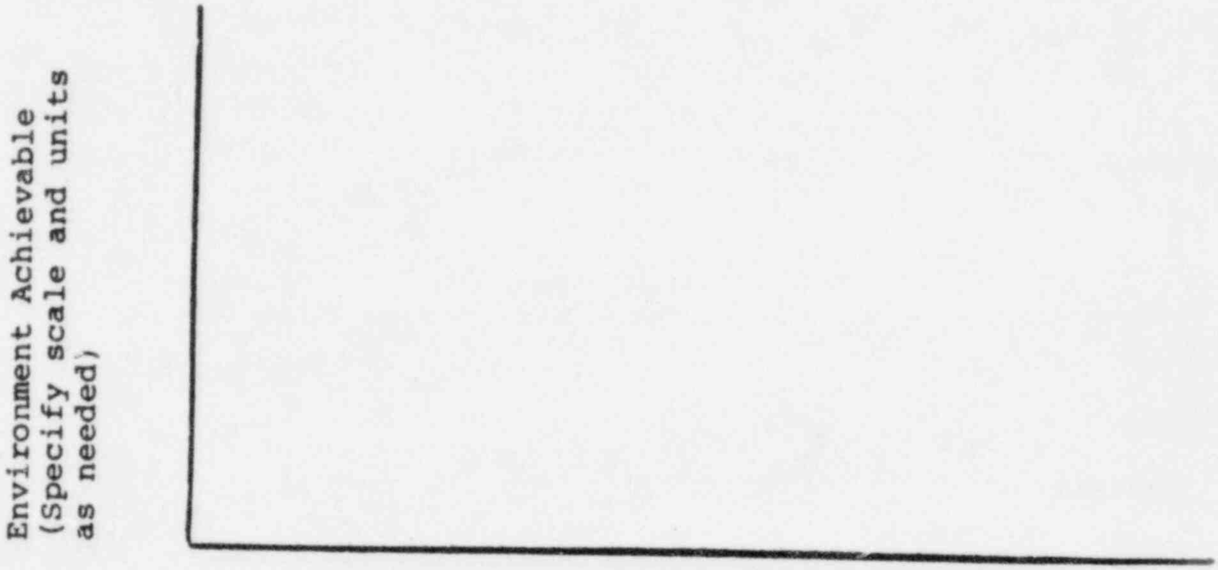
COMMENTS:

Complete This Section Only If You Can
Perform VIBRATION (NOT SEISMIC) Tests

1. What special equipment do you utilize for vibration tests?

2. Give the size/volume of equipment used for vibration tests.

3. Using the axes below, indicate the vibration test environment achievable as a function of size of equipment to be tested.



Largest Dimension of Equipment (or a similar expression of overall size limitations--specify scale and units as needed)

4. What are the rates of application of the vibration tests?

5. Are there limits to the time a vibration test can be continued?

Yes _____ No _____

If yes, what are these limits?

6. Can the vibration environment be actively varied during the test?

Yes _____ No _____

a. If yes:

i. How is the environment varied?

ii. What range of environments can be used?

iii. What is the smallest change possible?

b. If no, what manual variations can be made?

7. Where possible, give a rough cost estimate per test.

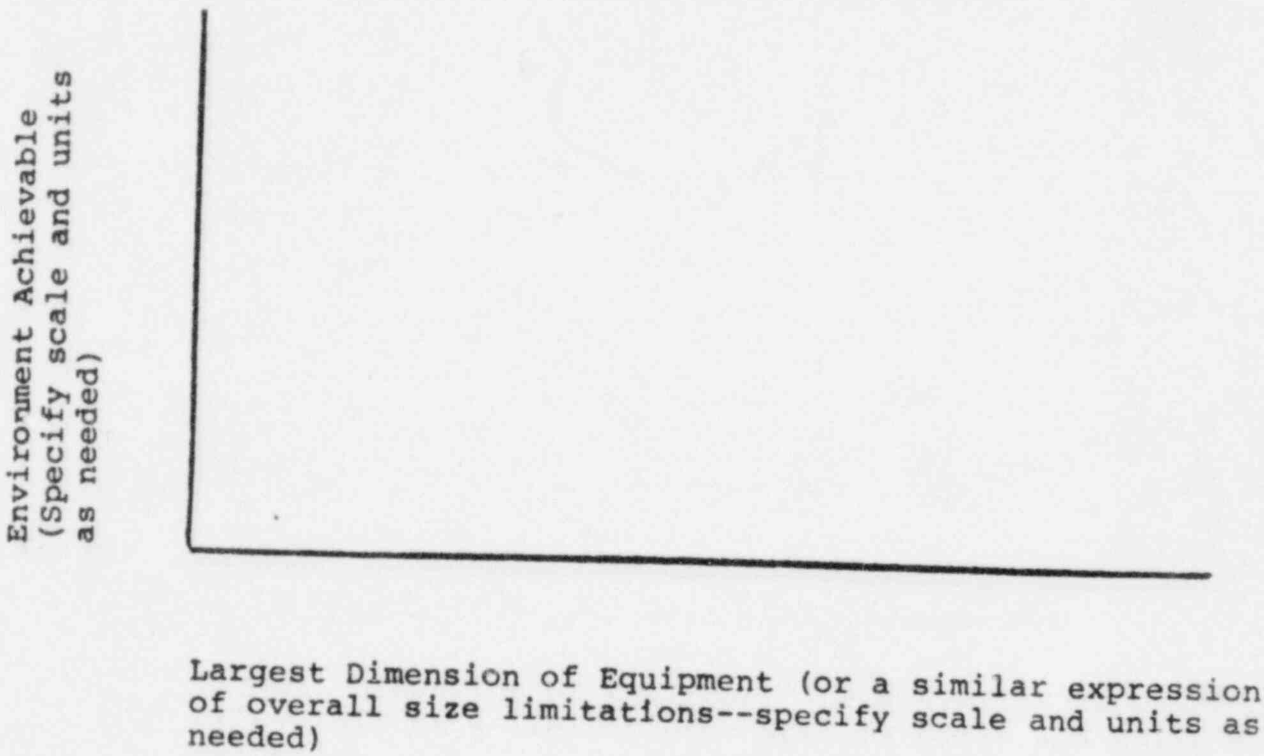
COMMENTS:

Complete This Section Only If You Can Perform SEISMIC CONDITION SIMULATION Tests

1. List the seismic condition simulation tests you can perform.

2. What special equipment do you utilize for seismic condition tests?

3. Using the axes below, indicate the seismic condition environment as a function of the size of equipment to be tested.



4. What are the rates of application of the seismic condition tests?

5. Are there limits to the time a seismic condition test can be continued?

   Yes _____ No _____

   If yes, what are these limits?

6. Can the seismic condition simulation be actively varied during the test?

Yes _____ No _____

a. If yes:

i. How are the conditions varied?

ii. What range of environments can be used?

iii. What is the smallest change that can be made?

b. If no, what manual variations can be made?

7. Where possible, give a rough cost estimate per test.

COMMENTS:

Complete This Section Only If You Can
Perform RADIATION Tests

1. Number of radiation chambers available _______.

2. Give size/volume of radiation chamber(s).

3. Give the size/volume of the chambers over which the flux does not vary over 20%; over 50%.

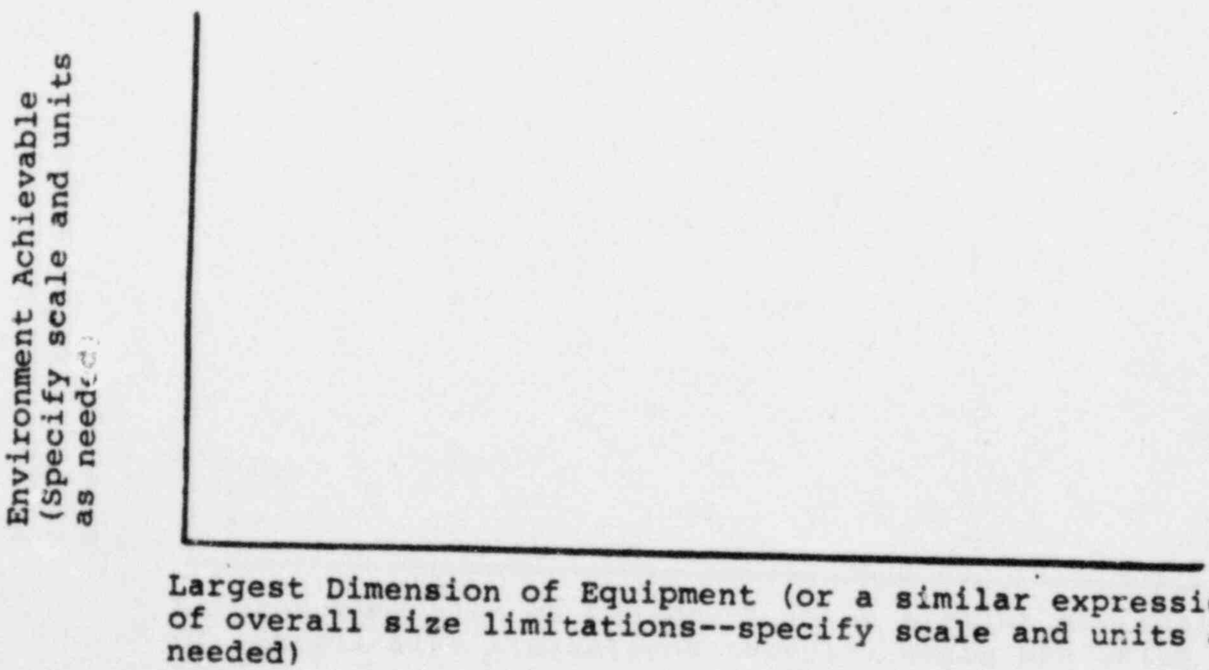
4. Are there limits on the length of time a radiation environment can be maintained?

   Yes _____ No _____

   If yes, please indicate limits.

5. What are the rates of application of a radiation test?

6. Using the axes below, indicate the radiation environment achievable as a function of the size of equipment to be tested.



7. What radiation sources are used?

8. Can dose rates be actively varied during the test?

Yes _____ No _____

a. If yes:

i. How is dose rate varied?

ii. What range of dose rates can be used?

iii. What is the smallest change that can be made?

b. If no, what manual variations can be made?

9. Can the radiation test be accomplished in other than air environments?

Yes _____ No _____

If yes, what environments can be accommodated?

COMMENTS:

Complete This Section Only If You Can Perform
SIMULTANEOUS STEAM and CHEMICAL SPRAY Tests

1. Number of chambers available for simultaneous steam and chemical spray tests _______.

2. Give the size/volume of the chamber(s).

3. Describe briefly the manner in which this test is performed.

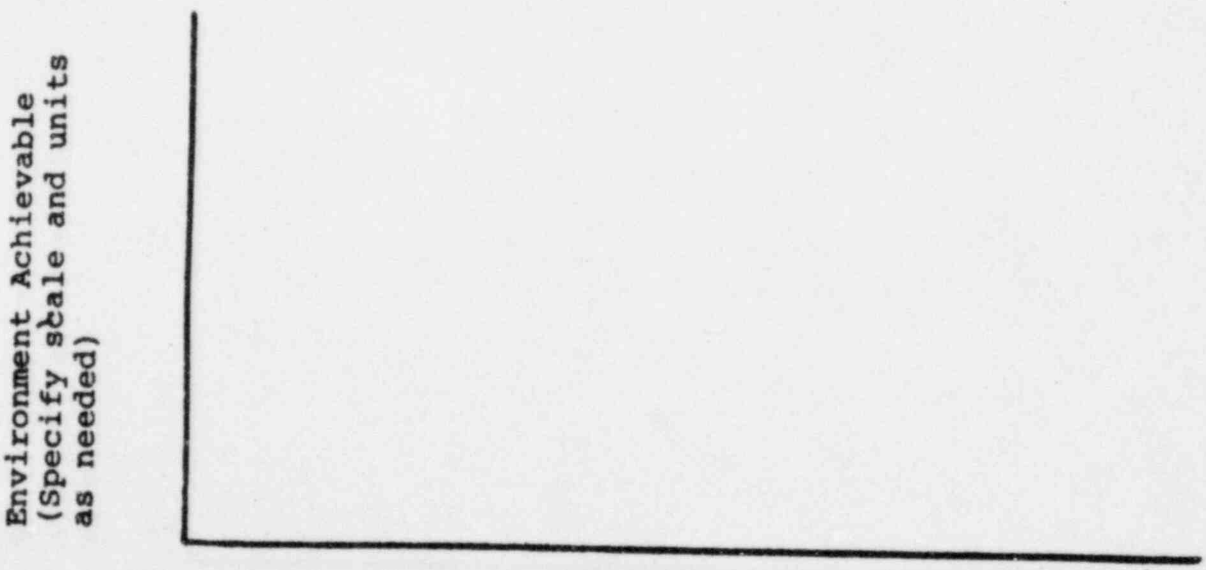
4. Is there a limit on the time that this environment can be maintained?

   Yes _____ No _____

   If yes, please indicate limit.

5. What are the rates of application for the simultaneous steam and chemical spray tests?

6. Indicate on the axes below, the simultaneous steam and chemical spray environment achievable as a function of size of equipment to be tested.



Largest Dimension of Equipment (or a similar expression of overall size limitations--specify scale and units as needed)

7. Can the environment be actively varied during the test?

Yes _____ No _____

a. If yes:

i. How are the conditions varied?

ii. What ranges of environments can be accommodated?

iii. What is the smallest change that can be made?

b. If no, what manual variations can be made?

8. Where possible, give a rough cost estimate per test.

COMMENTS:

Complete This Section Only If You Can Perform
SIMULTANEOUS STEAM, RADIATION and CHEMICAL SPRAY Tests

1. Number of chambers available for simultaneous steam, radiation and chemical spray tests _______.

2. Give the size/volume of the chamber(s).

3. Give the size/volume of chambers over which the radiation flux does not vary over 20%; over 50%.

4. Describe briefly the manner in which this test is performed.

5. What radiation source(s) are used in this test?

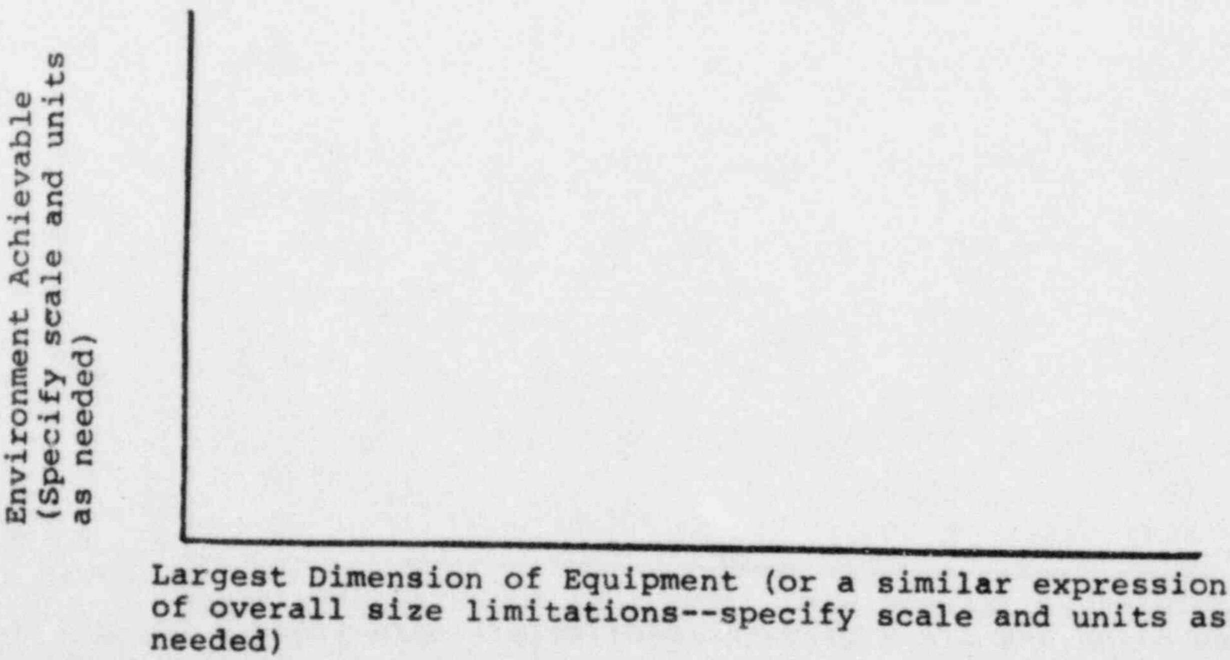
6. Is there a limit to the time this environment can be maintained?

   Yes _____ No _____

   If yes, please indicate limit.

7. What are the rates of application for the simultaneous steam, radiation and chemical spray tests?

8. Indicate on the axes below the simultaneous environment achievable as a function of size of equipment to be tested.



9. Can this environment be actively varied during the test?

Yes _____ No _____

a. If yes:

i. How are the variations accomplished?

ii. What is the range of environments achievable?

iii. What is the smallest change that can be made?

b. If no, what manual variations are possible?

10. Where possible, give a rough cost estimate per test.

COMMENTS:

Complete This Section Only If You Can Perform SIMULTANEOUS AGING (THERMAL AND RADIATION) AND HUMIDITY Tests

1. Number of chambers available for simultaneous aging and humidity tests _______.

2. Give the size/volume of the chamber(s).

3. Give the size/volume of chambers over which the radiation flux does not vary over 20%; over 50%.

4. Are there limits on the length of time the simultaneous environment can be maintained?

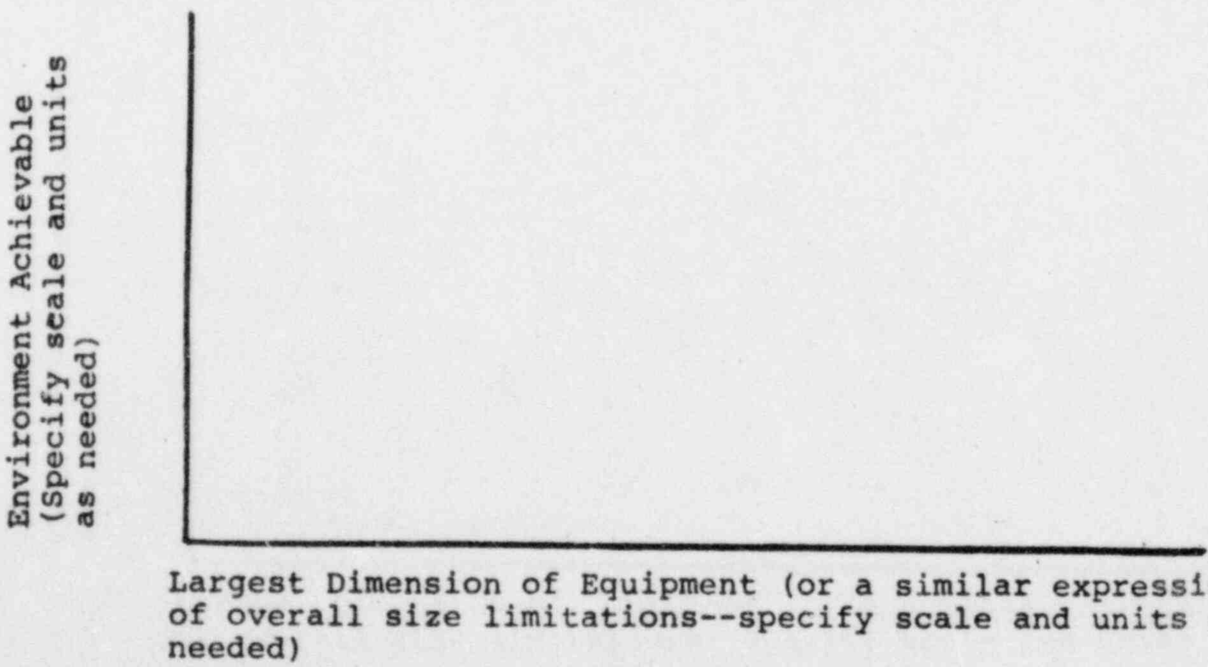
   Yes _____ No _____

   If yes, please indicate those limits.

5. What are the rates of application of the simultaneous test? (years/day)

6. What radiation source(s) are used in this test?

7. Indicate on the axes below the simultaneous environment achievable as a function of size of equipment to be tested.



8. Can this environment be actively varied during the test?

Yes _____ No _____

a. If yes:

i. How are the variations accomplished?

ii. What range of environments is achievable?

iii. What is the smallest change that can be made?

b. If not, what manual variations are possible?

9. Where possible, give a rough cost estimate per test.

COMMENTS:

Complete This Section Only If You Can Perform
SIMULTANEOUS Tests Not Discussed Previously

1. What other test procedures can be performed simultaneously?

2. Give the size/volume of special equipment or chambers you possess for simultaneous testing.

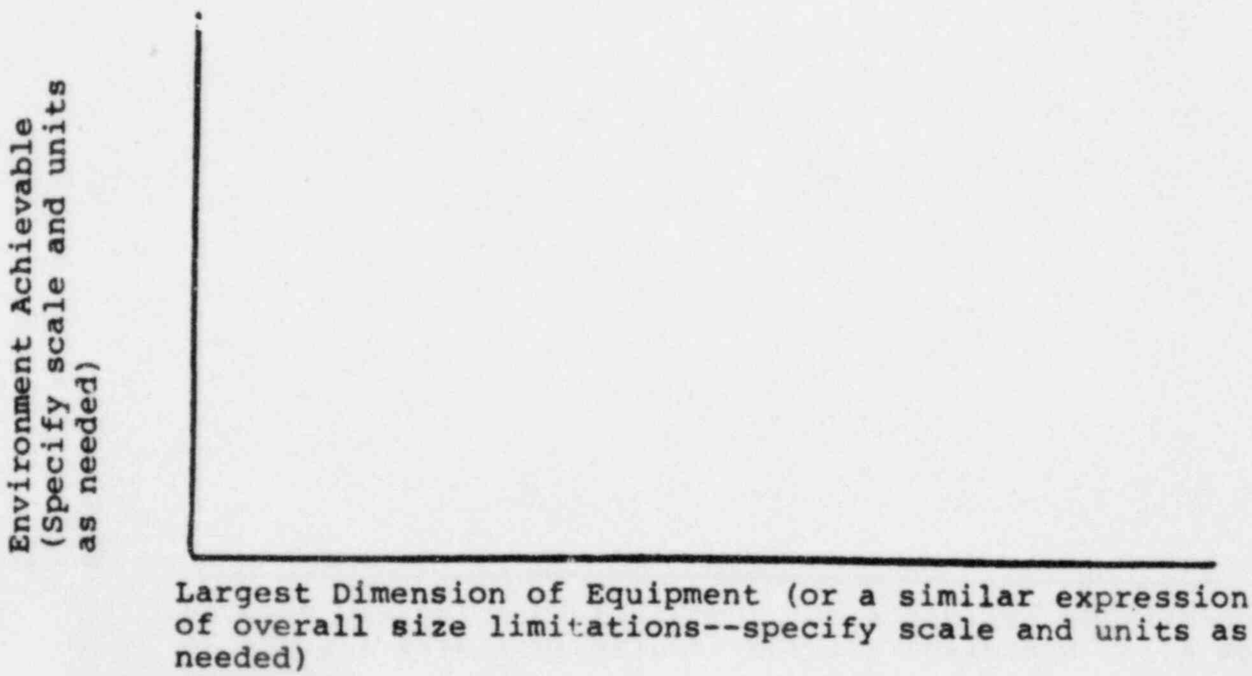
3. Are there limits to the time these simultaneous environments can be maintained?

Yes _____ No _____

a. If yes, please indicate limits.

4. What are the rates of application of the simultaneous tests?

5. Indicate on the axes below the simultaneous environment achievable as a function of the size of equipment to be tested.



6. Can this environment be actively varied during the test?

Yes _____ No _____

a. If yes:

i. How are the variations accomplished?

ii. What range of environments is achievable?

iii. What is smallest change that can be made?

b. If no, what manual variations are possible?

7. Where possible, give a rought cost estimate per test.

COMMENTS:

Initial Mailing List for Questionnaire

Acton Environmental Testing Corporation
Attn: R. S. Cowdrey
533 Main Street
Acton, MA 01720

Aerojet Nuclear Company
Attn: N. C. Kaufman
Idaho National Eng. Lab
550 Second Street
Idaho Falls, ID 83401

AETL
Attn: J. A. Brown
9551 Canoga Avenue
Chatsworth, CA 91311

Air Force Weapons Laboratory
Attn: A. Matucci
Kirtland Air Force Base
Albuquerque, NM 87115

Allied Chemical Corporation
Attn: O. L. Cordes
Idaho Chemical Programs - Operations Office
550 2nd Street
Idaho Falls, ID 83401

Allied Nuclear, Inc.
Attn: C. R. Flynn
4821 S. Loop East
Houston, TX 77033

American Environments Co., Inc.
Attn: J.S.K. Molnar
P. O. Box 222
Kings Park, NY 11754

Amersham Corp.
Attn: G. W. Dunbar, Jr.
2636 S. Clearbrook Dr.
Arlington Heights, IL 60005

Ames Laboratory
Attn: M. D. Voss
Iowa State University
Ames, IA 50011

Anaconda Wire and Cable Company
Attn: Dr. T. H. Ling
East 8th Street
Marion, IN 46953

Applied Nucleonics Co.
Attn: G. E. Howard
1701 Colorado Blvd.
Santa Monica, CA 90404

Approved Engineering Test Laboratories
Corporate Offices
15720 Ventura Blvd., Suite 608
Encino, CA 91436

Argonne National Laboratory
Attn: C. H. Youngquist
9700 South Cass Avenue
Argonne, IL 60439

Argonne National Laboratory
Attn: R. Curran/D. A. McKenzie
Box 2528
Idaho Falls, ID 83401

Atlantic Richfield Hanford Company
Attn: B. J. Saueressig
P. O. Box 250
Richland, WA 99352

Atomics International
Attn: J. D. Gylfe
8900 DeSoto Avenue
Canoga Park, CA 91304

Babcock & Wilcox
Attn: N. Burstein
P. O. Box 1260
Lynchburg, VA 24505

Bailey Meter Company
Attn: J. W. Malcolm
29801 Euclid Avenue
Wickliffe, OH 44092

Basic Technology, Inc.
Attn: J. H. Thomas
7125 Saltsburg Rd
Pittsburgh, PA 15235

Battelle Memorial Institute - Columbus
Attn: Jim McCall
505 King Avenue
Columbus, OH 43201

Battelle Memorial Institute - Columbus
Attn: W. A. Abbott
505 King Avenue
Columbus, OH 43201

Battelle Pacific Northwest Laboratory
Attn: F. Hungate
P. O. Box 999
Richland, WA 99352

Bechtel Corporation
Attn: K. Bailey
50 Beale Street
San Francisco, CA 94105

Bechtel Corporation
Attn: R. L. Ashley
1540 Shady Grove Rd.
Gaithersburg, MD 20760

BNP Nuclear Products
Attn: O. Reed
9000 Precision Dr.
Indianapolis, IN 46236

Brewer Engineering Laboratories, Inc.
Attn: G. A. Brewer
P. O. Box 288
Marion, MA 02738

Brookhaven National Laboratory
Attn: G. W. Bennett
Department of Applied Science
Associated Universities, Inc.
Upton, LI, NY 11973

Dayton T. Brown, Inc.
Attn: F. F. J. Peter
Church Street
Bohemia, Long Island
New York, NY 11716

J. A. Callanan Co.
Attn: R. Callanan
5677 Northwest Highway
Chicago, IL 60646

Calspan Corporation
Attn: F. A. Bierl
P. O. Box 235
Buffalo, NY 14221

Carboline Company
Attn: J. F. Montle
350 Hanley Industrial Court
St. Louis, MO 63144

Col-X Corp.
Attn: J. C. Lutz
981 E. Hudson
Columbus, OH 43211

Combustion Engineering
Attn: D. Sentell
1000 Prospect Hill Rd.
Windsor, CT 06095

Dunegan/Endevco
Attn: J. Ownby
Rancho Viejo Rd
San Juan Capistrano, CA 92675

Ebasco Services, Inc.
Attn: S. S. Christopher
2 Rector Street
New York, NY 10006

EG&G Idaho, Inc.
Idaho National Eng. Laboratory
Attn: N. C. Kaufman
P. O. Box 1625
Idaho Falls, ID 83401

Electrometer Corp.
Attn: A. Zirkes
P. O. Box 42377
Cincinnati, OH 45242

Engineering Applications & Technology
Attn: R. Perez
4676 Admiralty Way
Marina del Rey, CA 90291

Farr Co.
Attn: L. D. Greco
P. O. Box 92187, Airport Station
Los Angeles, CA 90009

Foxboro Company
Attn: J. Childs
Foxboro, MA 02035

The Franklin Institute Research Lab
Attn: Dr. S. P. Carfagno
The Benjamin Franklin Parkway
Philadelphia, PA 19103

General Electric Company
Attn: L. D. Test
175 Curtner Avenue
San Jose, CA 95114

Georgia Institute of Technology
Attn: Monte V. Davis
Neely Nuclear Center
225 No. Ave NW
Atlanta, GA 30332

Hanford Engineering Development Labs.
Westinghouse Hanford Company
Attn: C. Day
P. O. Box 1970
Richland, WA 99352

High Voltage Engineering Corp.
Attn: E. D. Gantt
So. Bedford St.
Burlington, MA 01803

Hittman Nuclear & Development Corp.
Attn: C. Mallory
9190 Red Branch Rd.
Columbia, MD 21045

Holosonics, Inc.
Attn: W. J. Kitson, Jr.
2400 Stevens Dr.
Richland, WA 99352

Institute for Resource Management, Inc.
Attn: B. Leonard
7815 Old Georgetown Rd.
Bethesda, MD 20014

International Neutronics
Attn: A. Chin
1237 N. San Antonio Rd.
Palo Alto, CA 94303

International Technology, Inc.
Attn: I. S. Tuba
7125 Saltsburg Rd.
Pittsburgh, PA 15235

IRT Corporation
Attn: Dr. N. A. Lurie
P. O. Box 80817
San Diego, CA 92138

Isomedix, Inc.
Attn: Dr. George R. Dietz
P. O. Box 177
Parsippany, NJ 07054

ITT Research Institute
Attn: I. Pincus
10 West 35th St.
Chicago, IL 60616

ITT General Controls
Attn: G. R. Brown
801 Allen Avenue
Glendale, CA 92101

Joy Manufacturing Co.
Attn: J. D. Bailey
338 S. Broadway
New Philadelphia, OH 44663

Kinemetrics
Attn: S. E. Pauly
222 Vista Ave.
Pasadena, CA 91107

Lambda Research, Inc.
Attn: P. S. Prevey
7213 Market Place
Cincinnati, OH 45216

Lawrence Livermore Laboratory
Attn: N. J. Alvares
P. O. Box 808
Livermore, CA 94550

Limitorque Corporation
Attn: W. J. Denkowski
King of Prussia, PA 19406

Los Alamos Scientific Laboratory
Attn: F. J. Fitzgibbon
P. O. Box 1663
University of California
Los Alamos, NM 87545

Materials Research, Inc.
Attn: R. Natesh
P. O. Box 225
Salt Lake City, UT 84110

Naval Research Laboratory
Attn: Frank J. Campbell
Code 6603F
Washington, DC 20375

Neutron Products, Inc.
Attn: M. M. Turkanis, Vice President
P. O. Box 68
Dickerson, MD 20753

Northrup Research and Technology Center
Attn: D. H. Rusling
One Research Park
P. V. Peninsula, CA 90274

Nuclear Components, Inc.
Attn: G. T. Ladd
Stockbridge Rd.
P. O. Box 60
Great Barrington, MA 01230

Nuclear Consulting Services, Inc.
Attn: J. W. Jacox
P. O. Box 29151
Columbus, OH 43229

Nuclear Environmental Engineering, Inc.
Attn: W. P. Peeples, Jr.
202 Medical Center Blvd.
Webster, TX 77598

Nuclear Fuel Services, Inc.
Attn: C. Moore
6000 Executive Blvd.
Rockville, MD 20852

Nuclear Science and Technology Facility
Div. of State University of NY at Buffalo
Attn: M. N. Haas
Rotary Blvd.
Buffalo, NY 14214

Nuclear Science Center
Texas A&M University
Attn: J. D. Randall
Box 89
College Station, TX 77843

Nuclear Sources & Services
Attn: R. D. Gallagher
P. O. Box 14023
Houston, TX 77021

Nuclear Systems, Inc.
Gamma Industries Div.
Attn: P. M. de Bruijn
2255 Ted Dunham Ave.
Baton Rouge, LA 70821

NUS Corporation
Attn: D. E. Bassett
4 Research Place
Rockville, MD 20850

NUSAC, Inc.
Attn: R. C. Adkins
7926 Jones Branch Rd.
McLean, VA 22101

Oak Ridge National Laboratories
Attn: G. Goldberg
P. O. Box X
Oak Ridge, TN 37830

Oak Ridge National Laboratory
Union Carbide Corporation
Attn: C. D. Cagle
P. O. Box X
Oak Ridge, TN 37830

Orlando Laboratories, Inc.
Attn: J. J. Hobbs
P. O. Box 8025-A
Orlando, FL 32806

Peabody Testing/X-ray Engineering Co.
Attn: R. L. Hilyard
1118 Chess Dr.
Foster City, CA 94404

Physics International
Attn: D. Lesser
2700 Merced St.
San Leandro, CA 94577

Plant Instrument Testing, Inc.
Attn: R. Kendrick
P. O. Box 19244
Dallas, TX 75219

The Wm. Powell Company
Attn: R. Koester
P. O. Box 14006
Cincinnati, OH 45214

Radiation Management Corp.
Attn: E. W. Scheirer
3508 Market St., Science Center Bldg. 2
Philadelphia, PA 19104

Radiation Technology, Inc.
Attn: M. A. Welt
Lake Denmark Rd.
Rockaway, NJ 07866

Raychem Corporation
Attn: F. E. LaFetra
300 Constitution Dr.
Melno Park, CA 94025

Reliance Electric Co.
Attn: W. G. Stiffles
24701 Euclid Ave.
Cleveland, OH 44117

Rockwell International
Attn: G. Talbott
400 N. Lexington Ave.
Pittsburg, PA 15208

Rockwell International
Atomics International Division
Rocky Flats Plant
Attn: W. D. Stump
P. O. Box 464
Golden, CO 80401

Rosemount Incorporated
Attn: I. Ismail
P. O. Box 35129
Minneapolis, MN 55435

Sandia Laboratories
Division 4432
Attn: L. L. Bonzon
Albuquerque, NM 87185

Sandia Laboratories
Division 1540
Attn: R. Brin
Albuquerque, NM 87185

Schumacher & Assoc. Inc.
Attn: J. Nevenzel
2550 Fair Oaks Blvd., Suite 120
Sacramento, CA 95825

Science Applications, Inc.
Attn: Dr. J. A. Naber
P. O. Box 2351
La Jolla, CA 92037

J. L. Shepherd and Assoc.
Attn: J. L. Shepherd
740 Salem St.
Glendale, CA 91203

Southern Service Co.
Attn: W. M. Pate
P. O. Box 2625
Birmingham, AL 35202

Southwest Research Institute
Attn: R. L. Bessey
P. O. Drawer 28510
San Antonio, TX 78284

Sundstrand Corporation
Attn: B. G. Wallin
2480 W. 70th Avenue
Denver, CO 80221

Sundstrand Energy Systems
Attn: D. MacMorris
4747 Harrison Ave.
Rockford, IL 61101

J. G. Sylvester Assoc., Inc.
Attn: L. Fernadez
900 Hingham St.
Rockland, MA 02370

United Nuclear Industries, Inc.
Attn: T. E. Dabrowski
P. O. Box 490
Richland, WA 99352

United States Testing Co., Inc.
Attn: W. Baumgartner
2800 George Washington Way
Richland, WA 99352

Universal Technical Testing Labs., Inc.
Attn: C. Modes
P. O. Box 372
Collingdale, PA 19023

University of Missouri
Attn: Julian Candle
Department of Nuclear Engineering
Columbia, MO

Westinghouse Electric Corporation
Attn: J. A. Logan
P. O. Box 2068
Idaho Falls, ID 83401

Westinghouse Electric Corp.
Attn: R. B. Miller
P. O. Box 355
Pittsburgh, PA 15230

White Sands Missile Range
Attn: L. Flores
White Sands, NM

Wyle Laboratories
Attn: P. M. Turkheimer
Director, Special Projects
128 Maryland St.
El Segundo, CA 90245

Wyle Laboratories
Attn: R. M. Scates
7800 Governors Dr. West
Hunstville, AL 35807

Table C-1

Organization Capabilities (Government or Government Contractor)

Company or Organization # /	Returned	Testing Div. of a Manufacturing Company	Testing Laboratory	Government Laboratory	Nonprofit Organization	Do you perform tests?	Would you perform tests for NRC?	Independent verification tests?	Is there another branch which performs tests?	1. Aging	a. Radiation	b. Thermal	c. Function Cycling	2. Humidity	3. Steam Environment	a. Saturated Steam	b. Superheated Steam	4. Pressure	5. Function	a. Mechanical	b. Electrical	6. Chemical Spray	7. Vibration (not seismic)	8. Seismic Condition Simulation	9. Radiation	Advertising material received?	
001 G	Y	-	-	Y	-	Y	Y	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Y	- -	Co-60 radiation facility; $300/day-$40/h for personnel
006 G	Y	N	N	Y	N	N	Y	Y	Other branch of company	Y	N	Y	N	Y	N	N	N	Y	Y	Y	Y	N	Y	N	N	No	
009 G	Y	N	N	Y	N																						
029 G																											
036 G																											Responded under another name
037 G/A																											
038 G	N																										Will not respond because of proprietary problems.
044 G	Y	-	-	Y	-	N																					
048 G	Y	-	-	-	-	N																					
050 G																											
053 G	Y	-	-	-	-	N	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		- -	No test capabilities.
055 G																											
056 G																											
071 G																											
074 G	Y	N	N	Y	N	Y	Y	Y	Y	Y	N	Y	Y	Y	N	N	N	Y	Y	Y	Y	N	Y	Y	N	Yes	QA procedures per applicable military & Sandia procedures
086 G	Y	N	N	Y	N																						May not respond because of proprietary problems
097 G	Y	N	N	Y	N	Y	Y	Y	N	N	N	N	N	N	N	N	N	N	Y	N	Y	N	N	N	Y	No	Sent some pictures & information
115 G																											
117 G	Y	N	N	Y	N																						
119 G	Y	N	N	Y	-	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	N	Y	N	Y	Yes	
124 G	Y	N	N	Y	N	N	Y	Y	N	Y	Y	Y	Y	N	Y	Y	N	N	Y	Y	Y	Y	N	N	Y	No	

Table C-1 (cont)

Company or Organization Key	AGING Subcontract	Simultaneous	Eqpt operation during test	QA Practices	How many tests in 6 months?	Advance Notice	Anticipated Upgrading	HUMIDITY Subcontract	Simultaneous	Eqpt operation during test	QA Practices	How many tests in 6 months?	Advance Notice	Anticipated Upgrading	STEAM ENVIRON. Subcontract	Simultaneous	Eqpt operation during test	QA Practices	How many tests in 6 months?	Advance Notice	Anticipated Upgrading	PRESSURE Subcontract	Simultaneous	Eqpt operation during test	QA Practices	How many tests in 6 months	Advance Notice	Anticipated Upgrading
001 G																												
008 G																												
009 G																												
020 G																												
036 G																												
037 G/A																												
038 G																												
044 G																												
048 G																												
050 G																												
053 G																												
055 G																												
056 G																												
071 G																												
074 G	*	Y	Y	Y	Variable >100	Weapons work has priority	N	*	Y	Y	Y	> 100	Weapons work has priority	N	-	-	-	-	-	-	-	*	N	Y	Y	~ 100	Weapon work has priority	N
096 G																												
097 G																												
115 G																												
117 G																												
119 G	N	Y	Not rad	Y	-	6 Weeks	-	N	-	-	-	-	-	-	N	-	-	-	-	-	-	N	Y	Y	Y	-	-	-
124 G	N	Y	Y	Y	5	1 - 2 months	Y	-	-	-	-	-	-	-	N	Y	Y	Y	5	None	Y	-	-	-	-	-	-	Y

*See other inputs from same organization.

Table C-1 (cont)

Company or Organization Key	FUNCTION Subcontract	Simultaneous	Eqpt operation during test	QA Practices	How many tests in 6 mo?	Advance Notice	Anticipated Upgrading	CHEM. SPRAY Subcontract	Simultaneous	Eqpt operation during test	QA Practices	How many tests in 6 mo?	Advance Notice	Anticipated Upgrading	VIBRATION Subcontract	Simultaneous	Eqpt operation during test	QA Practices	How many tests in 6 mo?	Advance Notice	Anticipated Upgrading	SEISMIC SIMUL. Subcontract	Simultaneous	Eqpt operation during test	QA Practices	How many tests in 6 mo?	Advance Notice	Anticipated Upgrading	RADIATION Subcontract	Simultaneous	Eqpt operation during test	QA Practices	How many tests in 6 mo?	Advance Notice	Anticipated Upgrading
001 G																																			
006 G																																			
009 G																																			
029 G																																			
036 G																																			
037 G																																			
038 G																																			
044 G																																			
046 G																																			
050 G																																			
053 G																																			
055 G																																			
056 G																																			
071 G																																			
074 G	*	N	Y	Y	> 100	Weapons work has priority	N	-	-	-	-	-	-	-	*	N	Y	Y	> 100	Weapons work has priority	N	*	N	Y	Y	> 100	Weapons work has priority	N							
086 G																																			
097 G	N	Y	Y	Y	?	1 month	Y																						N	Y	Y	Y	?	1 month	Y
115 G																																			
117 G																																			
119 G	N	-	-	-	-	-	-	-	-	-	-	-	-	-	N	Y	Y	Y	-	-	-	-	-	-	-	-	-	-	-	N	-	-	-	-	-
120 G	N	N	Y	-	-	-	Y	N	Y	Y	Y	?	None	Y	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	N	Y	Y	Y	1 - 2 months	Y

IMAGE EVALUATION
TEST TARGET (MT-3)

6″

MICROCOPY RESOLUTION TEST CHART

Table C-2

Organization Capabilities (Academia)

Company or Organization Key	Returned	Testing Div. of a Manufacturing Company	Testing Laboratory	Government Laboratory	Nonprofit Organization	Do you perform tests?	Would you perform tests for NRC?	Independent verification tests?	Is there another branch which performs tests?	1. Aging	a. Radiation	b. Thermal	c. Function cycling	2. Humidity	3. Steam Environment	a. Saturated Steam	b. Superheated Steam	4. Pressure	5. Function	a. Mechanical	b. Electrical	6. Chemical Spray	7. Vibration (not seismic)	8. Seismic Condition Simulation	9. Radiation	Advertising material received?	Comments
023 A	Y	N	N	N	Y	Y	Y	Y	Y	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Y	Yes	
040 A	N	-	-	-	Y	Y	Y	?	N	Y	Y	-	-	-	-	-	-	-	-	-	-	-	-	-	Y	- -	
079 A	Y	-	-	-	Univ.	Y	Y	Y	N	Y	Y	N	Y	Y	Y	Y	N	N	Y	N	Y	Y	N	N	Y	Yes	
089 A	Y	N	N	N	Y	N	Y	Y	N	Y	Y	Y	Y	N	Y	Y	N	N	N	N	N	N	Sub-contract	Sub-contract	Y	Yes	
123 A	Y	N	N	N	Y Univ	Y	Y	Y	N	Y															Y	No	

Table C-2 (cont)

Company or Organization Key	AGING Subcontract	Simultaneous	Eqpt operation during test	QA Practices	How many tests in 6 months?	Advance Notice	Anticipated Upgrading	HUMIDITY Subcontract	Simultaneous	Eqpt operation during test	QA Practices	How many tests in 6 months?	Advance Notice	Anticipated Upgrading	STEAM ENVIRON. Subcontract	Simultaneous	Eqpt operation during test	QA Practices	How many tests in 6 months?	Advance Notice	Anticipated Upgrading	PRESSURE Subcontract	Simultaneous	Eqpt operation during test	QA Practices	How many tests in 6 months?	Advance Notice	Anticipated Upgrading
025 A																												
040 A																												
079 A	N	Y	Y	Y	6 months	2 months	Y	N	Y	Y	Y	6 months	2 months	Y	N	Y	Y	Y	6 months	2 months	Y	-	-	-	-	-	-	-
089 A	N	-	-	-	-	< 1 month	Y	-	-	-	-	-	-	-	N	-	-	-	-	-	-	-	-	-	-	-	-	-
123 A																												

Anticipated upgrading to do all types.

Table C-2 (cont)

Company or Organization Key	FUNCTION Subcontract	Simultaneous	Eqpt operation during test	QA Practice	How many tests in 6 months?	Advance Notice	Anticipated Upgrading	CHEM. SPRAY Subcontract	Simultaneous	Eqpt operation during test	QA Practice	How many tests in 6 months?	Advance Notice	Anticipated Upgrading	VIBRATION Subcontract	Simultaneous	Eqpt operation during test	QA Practices	How many tests in 6 months?	Advance Notice	Anticipated Upgrading	SEISMIC SIMUL. Subcont. ct	Simultaneous	Eqpt operation during test	QA Practices	How many tests in 6 months?	Advance Notice	Anticipated Upgrading	RADIATION Subcontract	Simultaneous	Eqpt operation during test	QA Practices	How many tests in 6 months?	Advance Notice	Anticipated Upgrading
025 A																													N	N	Y	Y	-	Days - weeks	-
040 A																																			
079 A	N	Y	Y	Y	8 months	2 months	Y	N	Y	Y	Y	-	-	Y	-	-	-	-	-	-	-	-	-	-	-	-	-	-	N	Y	Y	Y	8 months	2 months	Y
089 A	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Y	-	-	-	-	-	-	Y	-	-	-	-	-	-	N	-	-	-	-	< 1 month	Y
123 A																													N	N	Y	Y	?	1 months	-

Table C-3

Organization Capabilities (Manufacturer and Testing Laboratory)

Company or Organization Key	Returned	Testing Div. of a Manufacturing Co.	Testing Laboratory	Government Laboratory	Nonprofit Organization	Do you perform tests?	Would you perform tests for NRC?	Independent verification tests?	Is there another branch which performs tests?	1. Aging	a. Radiation	b. Thermal	c. Function Cycling	2. Humidity	3. Environment	a. Saturated Steam	b. Superheated Steam	4. Pressure	5. Function	a. Mechanical	b. Electrical	6. Chemical Spray	7. Vibration (not seismic)	8. Seismic Condition Simulation	9. Radiation	Advertising material received?	Comments
002 M																											
003 TL	Y	Y	N	N	N	Y	Y	Y	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	Y	No	
004 M																											
005 M	Y																										
007 M	Y	Y	N	N	N	Y	Y	Y	Other branch of co.	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Yes	
008 TL																											
010 M																											
011 TL	Y	-	-	-	-	N	N	N	N																		
012 TL/M																											
013 M																											
014 M	Y	Y	N	N	N	N	Y	Y	N	Y	N	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	N	N	N	No	
015 TL																											
016 M	Y																										
017 TL	Y	-	Y	-	-	Y	Y	Y	N	Y	Sub-contract	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Sub-contract	Y	Y	Sub-contract	Yes	
018 M	Y	Y	N	N	N	N	Y	Y	N																Y	No	Do perform gamma scanning
019 M	Y	Y	N	N	N	Y	Y	Y	N	Y	Sub-contract	Y	Y	Sub-contract		Subcontract		Y	Y	Y	Y	Sub-contract	Y	Y	Sub-contract	None available	
020 M	Y					N																					
021 M																											
022 M																											
023 M	Y	N	Y	N	N	Y	Y	[illegible]	N	Y	Sub-contract	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	N	N	N	No	
024 M																											
026 TL	Y	N	Y	N	N	Y	Y	Y	N	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	N	Sub-contract	Y	No	2nd page of ? not included and thus rec'd from specific sections
027 M																											
028 M																											
030 M																											
031 M/TL																											

Table C-3 (cont)

Company or Organization Key	AGING Subcontract	Simultaneous	Eqpt operation during test	QA Practices	How many tests in 6 months?	Advance Notice	Anticipated Upgrading	HUMIDITY Subcontract	Simultaneous	Eqpt operation during test	QA Practices	How many tests in 6 months?	Advance Notice	Anticipated Upgrading	STEAM ENVIRON. Subcontract	Simultaneous	Eqpt operation during test	QA Practices	# really tests in 6 months?	Advance Notice	Anticipated Upgrading	PRESSURE Subcontract	Simultaneous	Eqpt operation during test	QA Practices	How many tests in 6 months?	Advance Notice	Anticipated Upgrading
002 M																												
003 TL																												
004 M																												
005 M																												
007 M	Radiation only	Y	Y	Y	1 to dozens	4 weeks	N	-	-	-	-	-	-	-	Possibly	Y	Y	Y	1 to dozens	4 weeks	-	N	Y	Y	Y	1 to dozens	4 weeks	N
008 TL																												
010 M																												
011 TL																												
012 TL/M																												
013 M																												
014 M	Y	-	-	-	-	-	-	-	-	-	-	-	-	-	Y sat'd	Y	-	Y	4-1/2 at 30 days ea	60 days	-	Y	Y	-	-	-	-	-
015 TL																												
016 M																												
017 TL	Radiation only	N	Y	Y	No limit	2 weeks	-	N	N	Y	Y	No limit	2 weeks	-	N	N	Y	Y	No limit	2 weeks	-	N	N	Y	Y	No limit	2 weeks	-
018 M																												
019 M	Radiation only	Function cyc only	N	Y	-	8 weeks	-	Y	-	-	Y	-	6 weeks	-	Y	-	-	Y	-	6 weeks	-	N	Y	Y	Y	-	8 weeks	-
020 M																												
021 M																												
022 M																												
023 M	Radiation only	Y	Y	Y	100	1 month	-	N	N	N	N	N	N	N	N	Y	Y	Y	100	1 month	-	N	Y	Y	Y	100	1 month	-
024 M																												
025 M	N	?	?	Y	?	?	?	N	-	-	-	-	-	-	N	?	?	?	?	?	?	N	?	?	?	?	?	?
027 M																												
028 M																												
030 M																												
031 M/TL																												

Table C-3 (cont)

Company or Organization Key	FUNCTION Subcontract	Simultaneous	Eqpt operation during test	QA Practices	How many tests in 6 months?	Advance Notice	Anticipated Upgrading	CHEM. SPRAY Subcontract	Simultaneous	Eqpt operation during test	QA Practices	How many tests in 6 months?	Advance Notice	Anticipated Upgrading	VIBRATION Subcontract	Simultaneous	Eqpt operation during test	QA Practices	How many tests in 6 months?	Advance Notice	Anticipated Upgrading	SEISMIC SIMUL. Subcontract	Simultaneous	Eqpt operation during test	QA Practices	How many tests in 6 months?	Advance Notice	Anticipated Upgrading	RADIATION Subcontract	Simultaneous	Eqpt operation during test	QA Practices	How many tests in 6 months?	Advance Notice	Anticipated Upgrading
002 M																																			
003 TL																																			
004 M																																			
005 M																																			
007 M	N	Y	Y	Y	1 to dozens	4 weeks	-	Y	Y	-	Y	1 to dozens	4 weeks	N	N	Y	Y	Y	1 to dozens	4 weeks	N	N	Y	Y	Y	1 to dozens	4 weeks	N	Y	N	N	Y	1 to dozens	4 weeks	-
008 TL																																			
010 M																																			
011 TL																																			
012 TL/M																																			
013 M																																			
014 M	Y	Y	Y	-	-	-	-	Y	Y	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
015 TL																																			
016 M																																			
017 TL	N	N	Y	Y	No limit	2 weeks	-	Y	N	Y	Y	No limit	2 weeks	-	N	N	Y	Y	No limit	3 weeks	-	N	.	Y	Y	No limit	2 weeks	-	Y	N	Y	Y	No limit	2 weeks	-
018 M																													N	Y	Y	Y	3	90 - 120 days	Y
019 M	N	Y	Y	Y	-	6 weeks	-	Y	-	-	Y	-	6 weeks	-	N	Y	Y	Y	-	6 weeks	-	N	Y	Y	Y	-	2 weeks	-	Y	N	N	Y	-	6 weeks	-
020 M																																			
021 M																																			
022 M																																			
023 M	N	Y	Y	Y	100	1 month	-	N	Y	Y	Y	100	1 month	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
024 M																																			
026 TL	N	?	?	?	?	?	?	N	?	?	?	?	?	?	-	-	-	-	-	-	-	Y	-	-	-	-	-	-	N	?	?	?	?	?	?
027 M																																			
028 M																																			
030 M																																			
031 M/TL																																			

Table C-3 (cont)

Company or Organization Key	Y Returned	Testing Div. of a Manufacturing Co.	Testing Laboratory	Government Laboratory	Nonprofit Organization	Do you perform tests?	Would you perform tests for NRC?	Independence verification tests?	Is there another branch which performs tests?	1. Aging	a. Radiation	b. Thermal	c. Function Cycling	2. Humidity	3. Steam Environment	a. Saturated Steam	b. Superheated Steam	4. Pressure	5. Function	a. Mechanical	b. Electrical	6. Chemical Spray	7. Vibration (not seismic)	8. Seismic Condition Simulation	9. Radiation	Advertising material received	Comments
033 M	Y	-	-	-	-	N																					Nontest qualification programs for safety related program
033 TL																											
034 TL																											
035 M	Y	-	-	-	-	N																					
039 M																											
041 M	Y	-	-	-	-	N																					
042 M																											
043 M	Y	-	-	-	-	N	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Might be able to do so in future
045 M	Y																										
047 M																											
048 M	Y	-	-	-	-	N																					
049 TL/G																											
051 TL	Y	N	Y	N	N	Y	Y	Y	Y	Y	Sub-contract	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Sub-contract	Yes	Other branches perform additional tests. Have own QA program.
054 M																											
057 TL	Y	N	Y	N	N	Y	Y	Y	N	Y	Sub-contract	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Sub-contract	No	
058 M/TL	Y	N	N	N	Y	N	N	N																			
059 TL	Y	N	Y	N	N	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Sub-contract	Y	Y	Y	Y	Y	Y	Sub-contract	Yes	
060 M																											
061 M																											
063 TL	Y																										
065 TL	Y	N	Y	N	N	Y	Y		N	Y	Y	Y	Y	N	N	N	N	N	Y	Y	Y	N	Y	Y	Y	No	Consulting, design and testing
066 TL/M	Y	N	Y	N	N	N	N	N	N																	Yes	
067 TL	Y	N	Y	N	Y	Y	Y	Y	N	Y	Sub-contract	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y sub-contract large	Y sub-contract larger	Sub-contract	No	
068 M																											
069 M/TL	Y	Y	_	_	_	N	N	N	N																		
070 M																											

Table C-3 (cont)

Company or Organization Key	AGING Subcontract	Simultaneous	Eqpt operation during test	QA Practices	How many tests in 6 months?	Advance Notice	Anticipated Upgrading	HUMIDITY Subcontract	Simultaneous	Eqpt operation during test	QA Practices	How many tests in 6 months?	Advance Notice	Anticipated Upgrading	STEAM ENVIRON. Subcontract	Simultaneous	Eqpt operation during test	QA Practices	How many tests in 6 months?	Advance Notice	Anticipated Upgrading	PRESSURE Subcontract	Simultaneous	Eqpt operation during test	QA Practices	How many tests in 6 months?	Advance Notice	Anticipated Upgrading
032 M																												
033 TL																												
034 TL																												
035 M																												
039 M																												
041 M																												
042 M																												
043 M																												
045 M																												
047 M																												
048 M																												
049 TL/C																												
051 TL	Radiation only	Y	Y	Y	50-144-200	1 - 3 weeks	-	N	Y	Y	Y	-	1 - 2 weeks	-	N	Saturated steam	Y	Y	84	1 - 2 weeks	-	N	Y	Y	Y	84	1 - 2 weeks	-
054 M																												
057 TL	Radiation only	Y	Y	Y	?	14 days	-	N	Y	Y	Y	?	10 days	-	N	Y	Y	Y	?	10 days	-	N	Y	Y	Y	?	14 days	-
058 M/TL																												
059 TL	N	Y	Y	Y	10	30 days	-	N	Y	Y	Y	10	30 days	-	N	Y	Y	Y	10	30 days	-	Y	N	Y	Y	10	30 days	-
060 M																												
061 M																												
063 TL																												
065 TL	N	N	Y	Y	12	3 weeks	N	-	-	-	-	-	-	Y	-	-	-	-	-	-	Y	-	-	-	-	-	-	Y
066 TL/M																												
067 TL	Subcont radiation	Y	Y	Y	10 - 20	Usually no backlog	-	N	Y	Y	Y	10	Usually no backlog	-	N	Y	Y	Y	10	Usually no backlog	-	N	Y	Y	Y	10	Usually no backlog	-
068 M																												
069 M/TL																												
070 M																												

Table C-3 (cont)

Company or Organization Key	FUNCTION Subcontract	Simultaneous	Eqpt operation during test	QA Practices	How many tests in 6 months?	Advance Notice	Anticipated Upgrading	CHEM. SPRAY Subcontract	Simultaneous	Eqpt operation during test	QA Practices	How many tests in 6 months?	Advance Notice	Anticipated Upgrading	VIBRATION Subcontract	Simultaneous	Eqpt operation during test	QA Practices	How many tests in 6 months?	Advance Notice	Anticipated Upgrading	SEISMIC SIMUL. Subcontract	Simultaneous	Eqpt operation during test	QA Practices	How many tests in 6 months?	Advance Notice	Anticipated Upgrading	RADIATION Subcontract	Simultaneous	Eqpt operation during test	QA Practices	How many tests in 6 months?	Advance Notice	Anticipated Upgrading
032 M																																			
033 TL																																			
034 TL																																			
035 M																																			
039 M																																			
041 M																																			
042 M																																			
043 M																																			
045 M																																			
047 M																																			
048 M																																			
049 TL/G																																			
051 TL	N	Y	Y	Y	200	1 - 2 weeks	-	N	Y	Y	Y	84	1 - 2 weeks	-	N	Y	Y	Y	50	1 - 2 weeks	-	N	Y	Y	Y	380	2 - 4 weeks	Y	Y	N	Y	Y	50	1 - 2 weeks	-
054 M																																			
057 TL	N	Y	Y	Y	?	14 days	-	N	Y	Y	Y	?	14 days	-	N	Y	Y	Y	?	14 days	-	N	Y	Y	Y	?	14 days	-	Y						
058 M/TL																																			
059 TL	N	Y	Y	Y	10	30 days	-	N	Y	Y	Y	10	30 days	-	N	N	Y	Y	10	30 days	-	N	Y	Y	Y	10	30 days	-	Y	Y	Y	Y	10	30 days	-
060 M																																			
061 M																																			
063 TL																																			
065 TL	N	Y	Y	Y	24	3 months	-	-	-	-	-	-	-	-	N	Y	Y	Y	24	3 months	-	N	Y	Y	Y	24	3 months	-	N	N	Y	Y	24	3 months	-
066 TL/M																																			
067 TL	N	Y	Y	Y	10	Usually no backlog	-	N	Y	Y	Y	10	Usually no backlog	-	Subcontract larger	N	Y	Y	10																
068 M																																			
069 M/TL																																			
070 M																																			

Table C-3 (cont)

Company or Organization Key	Returned	Testing Div. of Manufacturing Company	Testing Laboratory	Government Laboratory	Nonprofit Organization	Do you perform tests?	Would you perform tests for NRC?	Independent verification tests?	Is there another branch which performs tests?	1. Aging	a. Radiation	b. Thermal	c. Function Cycling	2. Humidity	3. Steam Environment	a. Saturated Steam	b. Superheated Steam	4. Pressure	5. Function	a. Mechanical	b. Electrical	6. Chemical Spray	7. Vibration (not seismic)	8. Seismic Condition Simulation	9. Radiation	Advertising materials received?	Comments
072 M																											
073 TL																											
075 M																											See letter in file.
076 M	Y	Y	N	N	N	N	N	N	N																		
077 TL	Y	N	Y	N	N	Y	Y	Y	Y*	Y	Sub-contract	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Sub-contract	Yes	*Other facility of same company.
079 M																											
080 M	Y																										
081 M																											
082 M																											
083 M/TL																											Indicated they responded. We never received.
084 M																											
085 M	Y	N	N	N	N	N	N	N	N																		
086 TL																											
087 TL	Y	_	Y	_	_	Y	Y	Y	N	N	N	N	N	N	N	N	N	N	Y	Y	Y	N	Y	-	-	Yes	Have own QA manual; QA tech developed for each test program
088 M																											
090 M																											
091 M/TL	Y	Y	N	Y	N	Y	Y	Y	N	N	N	N	N	Sub-contract Y	N	N	N	Y	N	N	N	N	Subcontract Y	Y	N	Yes	
092 TL	Y	N	N	N	Y	Y	Y	Y	Y*	Y	Y	Y	Y	Y	N	N	N	N	Y	Y	Y	N	Y	Y	Y	No	*Radiation lab does radiation aging.
093 M																											
094 M																											
095 M																											
098 TL	Y	N	Y	N	N	Y	Y	Y	N	Y	N	Y	N	Y	Y	N	Y	Y	Y	Y	Y	N	Y	N	Y	No	
100 M																											
101 M	Y	Y	N	N	N	Y	Y	Y	Y*	Y	Y	Y	Y	N	N	N	N	Y	Y	Y	Y	N	N	N	Y	No	*Other group of same co. does this testing, but do not respond.
102 TL																											
107 M	Y																										

Table C-3 (cont)

Company or Organization Key	AGING Subcontract	Simultaneous	Eqpt operation during test	QA Practices	How many tests in 6 months?	Advance Notice	Anticipated Upgrading	HUMIDITY Subcontract	Simultaneous	Eqpt operation during test	QA Practices	How many tests in 6 months?	Advance Notice	Anticipated Upgrading	STEAM ENVIRON. Subcontract	Simultaneous	Eqpt operation during test	QA Practices	How many tests in 6 months?	Advance Notice	Anticipated Upgrading	PRESSURE Subcontract	Simultaneous	Eqpt operation during test	QA Practices	How many tests in 6 months?	Advance Notice	Anticipated Upgrading
072 M																												
073 TL																												
075 M																												
076 M																												
077 TL	Radiation only	Y	Y	Y	100	1 - 2 weeks	-	N	Y	Y	Y	144	1 - 2 weeks	-	N	Y	Y	Y	72	4 weeks	-	N	Y	Y	Y	90	1 - 2 weeks	-
078 M																												
080 M																												
081 M																												
082 M																												
083 M/TL																												
084 M																												
085 M																												
086 TL																												
087 TL																												
088 M																												
090 M																												
091 M/TL	-	-	-	-	-	-	-	Y	N	Y	Y	-	6 months	-	-	-	-	-	-	-	-	N	N	Y	Y	?	8 months	-
092 TL	N	N	Y	Y	-	2 weeks	-	N	N	N	N	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
093 M																												
094 M																												
095 M																												
098 TL	N	N	Depends on equipment	Y	-	?	-	N	-	-	Y	-	?	-	N	-	-	Y	-	-	-	N	-	-	Y	-	-	-
100 M																												
101 M	N	Y	Y	Y	Depends	4 weeks min	N	-	-	-	-	-	-	-	-	-	-	-	-	-	-	N	N	Y	Y	Depends	4 weeks min	N
102 TL																												
103 M																												

Table C-3 (cont)

Company or Organization Key	FUNCTION Subcontract	Simultaneous	Sigl operation during test	QA Practice	How many tests in 6 months?	Advance Notice	Anticipated Upgrading	CHEM SPRAY Subcontract	Simultaneous	Sigl operation during test	QA Practice	How many tests in 6 months?	Advance Notice	Anticipated Upgrading	VIBRATION Subcontract	Simultaneous	Sigl operation during test	QA Practice	How many tests in 6 months?	Advance Notice	Anticipated Upgrading	SEISMIC SIMUL. Subcontract	Simultaneous	Sigl operation during test	QA Practice	How many tests in 6 months?	Advance Notice	Anticipated Upgrading	RADIATION Subcontract	Simultaneous	Sigl operation during test	QA Practice	How many tests in 6 months?	Advance Notice	Anticipated Upgrading
072 M																																			
073 TL																																			
075 M																																			
076 M																																			
077 TL	N	Y	Y	Y	300	1 - 2 weeks	-	N	Y	Y	Y	72	2 - 4 weeks	-	N	Y	Y	Y	75	1 - 2 weeks	-	N	Y	Y	Y	75	2 - 4 weeks	Y	Y	N -	Y	Y	50	1 - 2 weeks	-
078 M																																			
080 M																																			
081 M																																			
082 M																																			
083 M/TL																																			
084 M																																			
085 M																																			
086 TL																																			
087 TL	N	N	Y	Y	-	1 week	-	-	-	-	-	-	-	-	N	N	Y	Y	-	1 week	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
088 M																																			
090 M																																			
091 M/TL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Y	N	Y	Y	-	6 months	-	Y	N	Y	Y	-	6 months	-	-	-	-	-	-	-	-
092 TL		N	N	Y	-	-	-	-	-	-	-	-	-	-	N	N	Y	Y	40	2 weeks	-	N	N	Y	Y	48	2 weeks	-	N	N	Y	Y	30	2 weeks	-
093 M																																			
094 M																																			
095 M																																			
098 TL	N	-	-	Y	-	-	-	-	-	-	-	-	-	-	N	-	-	Y	-	-	-	-	-	-	-	-	-	-	N	-	-	Y	-	-	-
100 M																																			
101 M	N	Y	Y	Y	Depends	4 weeks/mon	N	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	N	Y	Y	Y	Depends	4 weeks min	N
102 TL																																			
103 M																																			

Table C-3 (cont)

Company or Organization Key	? Returned	Testing Div. of a Manufacturing Co.	Testing Laboratory	Government Laboratory	Nonprofit Organization	Do you perform tests?	Would you perform tests for NRC?	Independent verification tests?	Is there another branch which performs tests?	1. Aging	a. Radiation	b. Thermal	c. Function Cycling	2. Humidity	3. Steam Environment	a. Saturated Steam	b. Superheated Steam	4. Pressure	5. Function	a. Mechanical	b. Electrical	6. Chemical Spray	7. Vibration (not seismic)	8. Seismic Condition Simulation	9. Radiation	Advertising material received?	Comments
104 M																											
105 TL/G																											
106 M																											
107 M	Y	-	-	-	-	N	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	No test capabilities.
108 M																											
109 TL	Y																										No test capabilities.
110 M/G	Y	Y	N	N	N	-	-	-	-																		Not filled out for proprietary reasons.
111 TL																											
112 TL	Y	N	N	N	Y	N	Y	Y	N	Y	N	Y	Y	Y													
113 TL	Y	N	Y	N	N	Y	Y	Y	N																	No	
114 M	?																										
116 M																											
118 TL	?																										
120 M																											
121 M	Y	Y	N	N	N	Y	Y	Y	N	-	-	-	-	-	-	-	-	Y	-	-	-	-	-	-	-		
122 M																											
123 M	Y	Y Engineering organization with some laboratory facil.				N	N	N	Y	Y	N	Y	Y	Y	Y	Y	N	Y	Y	N	Y	N	N	Y	N	No	Do not perform work for NRC or others.

G - Government or Government Contractor; A - Academia; M - Manufacturer; TL - Testing Laboratory

Tabl . C-3 (cont)

Company or Organization Key	AGING Subcontract	Simultaneous	Rigid operation during test	QA Practices	How many tests in 6 months?	Advance Notice	Anticipated Upgrading	HUMIDITY Subcontract	Simultaneous	Rigid operation during test	QA Practices	How many tests in 6 months?	Advance Notice	Anticipated Upgrading	STEAM ENVIRON. Subcontract	Simultaneous	Rigid operation during test	QA Practices	How many tests in 6 months?	Advance Notice	Anticipated Upgrading	PRESSURE Subcontract	Simultaneous	Rigid operation during test	QA Practices	How many tests in 6 months?	Advance Notice	Anticipated Upgrading
104 M																												
105 TL/G																												
106 M																												
107 M																												
108 M																												
109 TL																												
110 M/G																												
111 TL																												
112 TL	N	-	-	-	-	-	Y	N	-	-	-	-	-	Y							Y							Y
113 TL																												
114 M																												
115 M																												
118 TL																												
120 M																												
121 M																												
122 M																												
125 M	N	N	N		-	-	-	N	N	Y	-	-	-	-	N	N	Y	-	-	-	-	N	N	Y	-	-	-	-

Table C-3 (cont)

Company or Organization Key	FUNCTION Subcontract	Simultaneous	High operation during test	QA Practice	How many tests in 6 months?	Advance Notice	Anticipated Upgrading	CHEM SPRAY Subcontract	Simultaneous	High operation during test	QA Practice	How many tests in 6 months?	Advance Notice	Anticipated Upgrading	VIBRATION Subcontract	Simultaneous	High operation during test	QA Practice	How many tests in 6 months?	Advance Notice	Anticipated Upgrading
104 M																					
105 TL/G																					
106 M																					
107 M																					
108 M																					
109 TL																					
110 M/G																					
111 TL																					
112 TL																					
113 TL																					
114 M																					
116 M																					
118 TL																					
120 M																					
121 M																					
122 M																					
125 M	N	N	Y	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Company or Organization Key	SEISMIC SIMUL. Subcontract	Simultaneous	High operation during test	QA Practice	How many tests in 6 months?	Advance Notice	Anticipated Upgrading	RADIATION Subcontract	Simultaneous	High operation during test	QA Practice	How many tests in 6 months?	Advance Notice	Anticipated Upgrading
104 M														
105 TL/G														
106 M														
107 M														
108 M														
109 TL														
110 M/G														
111 TL														
112 TL														
113 TL														
114 M														
116 M														
118 TL														
120 M														
121 M														
122 M														
125 M	N	N	Y	-	-	-	-	-	-	-	-	-	-	-

Table C-4

Select Government or Government-Contractor

Organization Number 001
NL = Not listed
n/a = Not applicable

	AGING	Thermal	Radiation	Combined	HUMIDITY	STEAM ENVIRONMENT	Superheated	Saturated	PRESSURE	FUNCTION	Mechanical	Electrical	CHEMICAL SPRAY	VIBRATION	SEISMIC SIMULATION CONDITION	RADIATION	STEAM & CHEMICAL SPRAY	STEAM, RADIATION & CHEMICAL SPRAY	AGING & HUMIDITY	OTHER:	OTHER:	OTHER:
1. Number of Chambers	NL				NL	NL			NL	NL			NL	NL	NL	1	NL	NL	NL			
2. Size/Volume of Chambers																Converted hot cell 2688 ft^3						
3. a. Size/Volume Over Which Flux Doesn't Vary More Than: 20%																*						
50%																*						
b. Radiation Sources Used																Co-60 rods (4)						
4. Length of Time Environment Can Be Maintained if Limited																Limited by use by others. Several can be done simultaneously						
5. a. Rate of Application of Environment																6.5x10^5 rads/h at 12 in. from center of source array						
b. How Rapidly Can Environment Be Established?																						
6. Active Variation of Environment																						
a. How accomplished																Manually changing distance from source						
b. Range achievable																6.5x10^5 rad/h @ 12 in. 5x10^3 rad/h @ 70 in.						
c. Smallest possible change																10%						
d. Manual variations																Test can be stopped & no. of sources varied.						
7. Other Than Air Environments																Whatever can be accommodated in 3 ft^3 to 4 ft^3 box or chamber.						
8. Cost Estimate per Test																NL						

*Provided in an attachment

Table C-4 (cont)

Organization No. 006
NL - Not listed
n/a - Not applicable

	AGING	Thermal	Radiation	Combined	HUMIDITY	STEAM ENVIRONMENT	Superheated	Saturated	PRESSURE	FUNCTION	Mechanical	Electrical	CHEMICAL SPRAY	VIBRATION	SEISMIC SIMULATION CONDITION	RADIATION	STEAM & CHEMICAL SPRAY	STEAM, RADIATION & CHEMICAL SPRAY	AGING & HUMIDITY	OTHER:	OTHER:	OTHER:
1. Number of Chambers		15	NL		3	NL			3		None	None	NL		NL	NL	NL	NL	NL			
2. Size/Volume of Chambers		Up to 420 ft^3			Up to 420 ft^3				20000 in^3 42 ft^3 for internal pressure		n/a	n/a		27,000 lb shaker								
3. a. Size/Volume Over Which Flux Doesn't Vary More Than:																						
20%		n/a			n/a				n/a		n/a	n/a		n/a								
50%		n/a			n/a				n/a		n/a	n/a		n/a								
b. Radiation Sources Used		n/a			n/a				n/a		n/a	n/a		n/a								
4. Length of Time Environment Can Be Maintained if Limited		NL			n/a				n/a		n/a	n/a		n/a								
5. a. Rate of Application of Environment		Any			Place test unit in chamber established				100 psi max		Any	Any		?								
b. How Rapidly Can Environment Be Established?					at T and humidity																	
6. Active Variation of Environment																						
a. How accomplished		Programmed			Programmed				Regulators		Manual	Manual		NL								
b. Range achievable		n/a			10-99% RH				0-100 psi		?	?		NL								
c. Smallest possible change		n/a			~ 5%				0.5 psi		?	?		NL								
d. Manual variations		NL			NL				NL		NL	NL		Stop and reprogram								
7. Other Than Air Environments		N_2 etc. No explosive gases or vapors			n/a				n/a		n/a	n/a		n/a								
8. Cost Estimate per Test		NL			NL				To variable to estimate		NL	NL		NL								

Table C-4 (cont)

Organization No. 074
NL = Not listed
n/a = not applicable

	AGING	Thermal	Radiation	Combined	HUMIDITY	STEAM ENVIRONMENT	Superheated	Saturated	PRESSURE	FUNCTION	Mechanical	Electrical	CHEMICAL SPRAY	VIBRATION	SEISMIC SIMULATION CONDITION	RADIATION	STEAM & CHEMICAL SPRAY	STEAM, RADIATION & CHEMICAL SPRAY	AGING & HUMIDITY	OTHER:	OTHER:	OTHER:
1. Number of Chambers		~ 50 various capabilities	NL		11	NL			Several		Do customized testing of any kind		None	(See 074 Section F)		NL	NL	NL	NL			
2. Size/Volume of Chambers		Min. 1 ft³ Max. 3950 ft³			See Manual Sec. B 2, 3, 4				83 ft³ x 1000 psig		NL	NL	22.7 ft³ salt fog 135 ft³ salt fog, rain	NL	NL							
3. a. Size/Volume Over Which Flux Doesn't Vary More Than: 20%		n/a			n/a				n/a				n/a									
50%		n/a			n/a				n/a				n/a									
b. Radiation Sources Used		n/a			n/a				n/a				n/a									
4. Length of Time Environment Can Be Maintained if Limited		n/a			n/a				n/a				n/a									
5. a. Rate of Application of Environment		Shock 400°F/5 min. 300°F/2 min.			Within minutes				Shock facilities very rapid as above				4-8 in./h									
b. How Rapidly Can Environment Be Established?									in minutes													
6. Active Variation of Environment		Automatic controllers			Automatic controllers				Automatic controllers				Controllers									
a. How accomplished																						
b. Range achievable		n/a			NL				0 - 1000 psig				Rain 4-8 in./h									
c. Smallest possible change		n/a			Continuously variable between ranges				Continuously variable				Continuously variable									
d. Manual variations		NL			NL				NL				NL									
7. Other Than Air Environments		Salt fog, rain, humidity shock			n/a				n/a				n/a									
8. Cost Estimate per Test		?			?				NL				N/L See 074 Sec. R									

Table C-4 (cont)

Organization No. 097
NL = Not listed
n/a = Not applicable

	AGING	Thermal	Radiation	Combined	HUMIDITY	STEAM ENVIRONMENT	Superheated	Saturated	PRESSURE	FUNCTION	Mechanical	Electrical	CHEMICAL SPRAY	VIBRATION	SEISMIC SIMULATION CONDITION	RADIATION	STEAM & CHEMICAL SPRAY	STEAM, RADIATION & CHEMICAL SPRAY	AGING & HUMIDITY	OTHER:	OTHER:	OTHER:
1. Number of Chambers	NL				NL	NL			NL	NL			NL	NL	NL	4 facilities	NL	NL	NL			
2. Size/Volume of Chambers																4000 ft^3 to 47500 ft^3						
3. a. Size/Volume Over Which Flux Doesn't Vary More Than:																ϕ decreases as ~ $1/r^2$ from source centerline						
20%																						
50%																						
b. Radiation Sources Used																γ and n						
4. Length of Time Environment Can Be Maintained if Limited																Unsched. maint. and repairs						
5. a. Rate of Application of Environment																ea γ: 10^8 - 10^9 r/s n: 10^{10} - 10^{14} n/cm^2/50 μs						
b. How Rapidly Can Environment Be Established?																						
6. Active Variation of Environment																t, distance intensity						
a. How accomplished																						
b. Range achievable																ea γ: 10^6 - 10^9 rad/s n: 10^{14} n/cm^2/50 μs						
c. Smallest possible change																steady state 10%						
d. Manual variations																NL						
7. Other Than Air Environments																Self-contained chambers						
8. Cost Estimate per Test																NL						

Table C-4 (cont)

Organization No. 119
NL = Not listed
n/a = Not applicable

	AGING	Thermal	Radiation	Combined	HUMIDITY	STEAM ENVIRONMENT	Superheated	Saturated	PRESSURE	FUNCTION	Mechanical	Electrical	CHEMICAL SPRAY	VIBRATION	SEISMIC SIMULATION CONDITION	RADIATION	STEAM & CHEMICAL SPRAY	STEAM, RADIATION & CHEMICAL SPRAY	AGING & HUMIDITY	OTHER:	OTHER:	OTHER:
1. Number of Chambers		14	1		1		8 auto-claves	8 auto-claves	10		1	NL	NL		NL	3 thermal reactors 1 HP cal facility	NL	NL	NL			
2. Size/Volume of Chambers		1000 in.^{3} to 24 ft.^{3}	346 in.^{3}		0.2 m^3		151 in.^{3} to 6100 in.^{3}	151 in.^{3} to 6100 in.^{3}	1.02 m^3		35 in.^{3}			200 force lb		11 in.^{3} to 254 in.^{3} inpile facility holes						
3. a. Size/Volume Over Which Flux Doesn't Vary More Than: 20%		n/a	346 in.^{3}		n/a		n/a	n/a	n/a		n/a			n/a		as above						
50%		n/a	346 in.^{3}		n/a		n/a	n/a	n/a		n/a			n/a		as above						
b. Radiation Sources Used		n/a	ATR reactor fuel elements		n/a		n/a	n/a	n/a		n/a			n/a		Nuclear test reactors 3-Cs-137 source (100 mci-180 ci)						
4. Length of Time Environment Can Be Maintained if Limited		n/a	n/a		n/a		n/a	n/a	n/a		~ 1 month			n/a except for equipment life		Limited to reactor shutdown/cycle over ATR-96% utilization factor ETR 2/3 wks operation/yr.						
5. a. Rate of Application of Environment		Per customer requirement	$3.0x10^8$ rad/h (fission product spectrum)		2 h		Static conditions up to 650°F, 2500 psig		Controlable to 1 ms for 10-90% change		.0031 in/min to 2 in./s Up to 30 Hz cycle load			Systems may be operated man. or auto. sweep control on acceleration		$5.75x10^{14}$ NV (thermal) $5.25x10^{14}$ NV (fast)						
b. How Rapidly Can Environment Be Established?														displacement or velocity, slow or fast sweep		20W/GM-c gamma heating HP-.01MR/h to 200 R/h						
6. Active Variation of Environment		Chamber controls (thermal chambers)	No		Chamber controls		By varying T, P, or H_2O injection		Controls on pressure source		Closed loop servo-hydraulic w/input from function generator			Yes		Positioning w/electro-mechanical system remote control						
a. How accomplished														NL								
b. Range achievable		n/a	n/a		20-90% RH dependent on temp.		200°F - 650°F 2500 psig		To 42 MPa future to 82 MPa		Static or slow dynamic 25-60 000 ½ cycle to 30 Hz 1-10 000 lb			NL		Test reactors 0 - max HP background to 200R/h						
c. Smallest possible change		n/a	n/a		2%		Anything within limits of equip capability		68 Pa		±5 lb			NL		Rad source with 0.1 in. accuracy reactors ~ 1%						
d. Manual variations		NL	Positioning or shrouding experiment		NL		NL	NL	NL		are possible			NL		NL						
7. Other Than Air Environments		N_2O, gases	H_2O, gases		n/a		n/a	n/a	n/a		n/a			NL		HP facility: Air only in rabbit facility, gas, liquids metals as encapsulated						
8. Cost Estimate per Test		$23-$35 per man/h	~ $30 per man/h		$23/h		$23/h	$23/h	$23/h		$35/h			NL		NL						

Thermal envir. can be obtained by placing environmental chamber over table and varied chamber capacities, auto. or man.

Table C-4 (cont)

Organization No. 124
NL = Not listed
n/a = Not applicable

	AGING	Thermal	Radiation	Combined	HUMIDITY	STEAM ENVIRONMENT	Superheated	Saturated	PRESSURE	FUNCTION	Mechanical	Electrical	CHEMICAL SPRAY	VIBRATION	SEISMIC SIMULATION CONDITION	RADIATION	STEAM & CHEMICAL SPRAY	STEAM, RADIATION & CHEMICAL SPRAY	AGING & HUMIDITY	OTHER:	OTHER:	OTHER:
1. Number of Chambers		1	1	1	n/a		n/a	1	n/a		None	None	1	n/a	n/a	1	1	1	n/a			
2. Size/Volume of Chambers		675 in.^{3}	675 in.^{3}	675 in.^{3}				675 in.^{3}			n/a	n/a	675 in.^{3}			675 m^3	675 in.^{3}	675 in.^{3}				
3. a. Size/Volume Over Which Flux Doesn't Vary More Than:																						
20%		n/a	28 in.^{3}	28 in.^{3}				n/a			n/a	n/a	n/a			28 in.^{3}	n/a	28 in.^{3}				
50%		n/a	56 in.^{3}	56 in.^{3}				n/a			n/a	n/a	n/a			56 in.^{3}	n/a	56 in.^{3}				
b. Radiation Sources Used		n/a	Co-60	Co-60				n/a			n/a	n/a	n/a			Co-60	n/a	Co-60				
4. Length of Time Environment Can Be Maintained if Limited		n/a	n/a	n/a				n/a			n/a	n/a	2 gal/h for 24 h			n/a	n/a	n/a				
5. a. Rate of Application of Environment		5 days @ 130°C	8 days @ 1 Mrad/h	5 days @ 0.2 Mrad/h				70 psig or lower			As required	Usually AC @ 60 Hz others available	2 gal/h nominal			From 5 days @ 0.2 Mrad/h	70 psi steam 2 gph chemical	Rad: 0.2→4 Mrad/h Steam 70 psi Sprays 2 gph				
b. How Rapidly Can Environment Be Established?		n/a	n/a	n/a				0 → 70 psig in 10 s 70 psig indef.				n/a	n/a			to 8 days @ 1 Mrad/h NL	NL	n/a				
6. Active Variation of Environment a. How accomplished		Automatic with T controller	Manual	Manual				Manually or automatic regulator			Remotely	Remotely	Manual pump capacity controls			Manual	Manual	Manual				
b. Range achievable		n/a	.1 → 1.0 Mrad/h	.1 → 1.0 Mrad/h				1 → 75 psig			NL	1 → 150 V 0 → 20 amp 60 Hz	1 - 10 g/h			0.1 → 10 Mrad/h	0 → 70 psi Steam 1→10 gph chemical	2→5 Mrad/h 0→70 psi 1-10 gph				
c. Smallest possible change		n/a	~ 10%	~ 10%				1 psig			NL	10 V 1 amp	NL			~ 10%	2 psi Steam 1% spray	rad: 40% Steam: 2 psi spray: 10%				
d. Manual variations		n/a	Source position control	Source position control				Manual isolation valves to throttle			NL	NL	NL			Source position control	n/a	n/a				
7. Other Than Air Environments		He, N_2	He, N_2	He, N_2				n/a					H_3BO_3 & H_3BO_3/NaOH			H_2O	n/a	n/a				
8. Cost Estimate per Test		$9000	$9000	$9000				NL			~ $3000	~ $3000	~ $3000			NL	$10,000/test	$20,000/test				

Table C-5

Select Academia

Organization No. 025
NL = Not listed
n/a = Not applicable

	AGING	Thermal	Radiation	Comb'd	HUMIDITY	STEAM ENVIRONMENT	Superheated	Saturated	PRESSURE	FUNCTION	Mechanical	Electrical	CHEMICAL SPRAY	VIBRATION	SEISMIC SIMULATION CONDITION	RADIATION	STEAM & CHEMICAL SPRAY	STEAM, RADIATION & CHEMICAL SPRAY	AGING & HUMIDITY	OTHER:	OTHER:	OTHER:
1. Number of Chambers	NL				NL	NL			NL		1		NL	NL	NL	>10		NL	NL			
2. Size/Volume of Chambers											15,900 in³					30 cm³ to 10^5 cm³						
3. a. Size/Volume Over Which Flux Doesn't Vary More Than:																						
20%																30 cm³						
50%																> 2000 cm³						
b. Radiation Sources Used																10 MW research reactor						
4. Length of Time Environment Can Be Maintained if Limited											Subject to current research demands					No ave., 150 h/wk						
5. a. Rate of Application of Environment											DC to 900 Hz etc.	DC			φ peak ~ γ peak ~	6×10^4 n/cm²s neutron 4×10^9 R/h-γ						
b. How Rapidly Can Environment Be Established?																						
6. Active Variation of Environment a. How accomplished											Program controller system similar to MTS series 810					Sample or shield movement power level variation						
b. Range achievable										Force: Velocity:	0-11 Kip 0-30 in./s				φ 10^{14} γ 10^9	n/cm²s & down R/h & down						
c. Smallest possible change											Force: ±0.5% of max.					<1%						
d. Manual variations											NL	NL				NL						
7. Other Than Air Environments											n/a	n/a				Water, gases, etc.						
8. Cost Estimate per Test											Negotiated on basis of man-h and machine time required					NL						

Table C-5 (cont)

Organization No. 040
NL - Not listed
n/a - Not applicable

	AGING	Thermal	Radiation	Combined	HUMIDITY	STEAM ENVIRONMENT	Superheated	Saturated	PRESSURE	FUNCTION	Mechanical	Electrical	CHEMICAL SPRAY	VIBRATION	SEISMIC SIMULATION CONDITION	RADIATION	STEAM & CHEMICAL SPRAY	STEAM, RADIATION & CHEMICAL SPRAY	AGING & HUMIDITY	OTHER:	OTHER:	OTHER:
1. Number of Chambers	NL				NL	NL			NL	NL			NL	NL	NL	1	NL	NL	NL			
2. Size/Volume of Chambers																2880 ft^3 room & small canisters that can be rotated in core face						
3. a. Size/Volume Over Which Flux Doesn't Vary More Than: 20%																48 ft^3						
50%																240 ft^3						
b. Radiation Sources Used																Reactor						
4. Length of Time Environment Can Be Maintained if Limited																NL						
5. a. Rate of Application of Environment																~ 7.5x10[illegible] n/cm^2 s 2.25 Mrad/h γ $2.25x10^4$ R/h n						
b. How Rapidly Can Environment Be Established?																						
6. Active Variation of Environment a. How accomplished																NL						
b. Range achievable																						
c. Smallest possible change																						
d. Manual variations																						
7. Other Than Air Environments																						
8. Cost Estimate per Test																						

Table C-5 (cont)

Organization No. 079
NL = Not listed
n/a = Not applicable

	AGING	Thermal	Radiation	Combined	HUMIDITY	STEAM ENVIRONMENT	Superheated	Saturated	PRESSURE	FUNCTION	Mechanical	Electrical	CHEMICAL SPRAY	VIBRATION	SEISMIC SIMULATION CONDITION	RADIATION	STEAM & CHEMICAL SPRAY	STEAM, RADIATION & CHEMICAL SPRAY	AGING & HUMIDITY	OTHER:	OTHER:	OTHER:
1. Number of Chambers		NL	3 min.		NL	NL			NL	NL			NL	NL	NL	NL	NL	Preliminary system has been designed	NL			
2. Size/Volume of Chambers			180 in.^{3} to 343 ft^3															343 ft^3				
3. a. Size/Volume Over Which Flux Doesn't Vary More Than:																						
20%			180 in.^{3} to 125 ft^3															5 ft^3				
50%			1017 in.^{3}															10 ft^3				
b. Radiation Sources Used			Nuclear Reactor															6% enrichment test reactor spectra match power reactors				
4. Length of Time Environment Can Be Maintained if Limited			n/a															n/a				
5. a. Rate of Application of Environment			Incore: 4×10^{13} n/cm^2 s Stand pipe: 1×10^{13} n/cm^2 s															70→320°F in 4 s				
b. How Rapidly Can Environment Be Established?			3×10^{7} R/h γ dry chamber: 1×10^{11} n/cm^2 s 10^{6} R/h γ																			
6. Active Variation of Environment a. How accomplished			Power or Position															Electrical or Manual Control				
b. Range achievable			Decades															Up to 320°F, 1×10^{11} n/cm^2/s 1.15 H_3BO_3 10^6 R/h γ				
c. Smallest possible change			1 %															1%				
d. Manual variations			NL															All				
7. Other Than Air Environments			H_2O															n/a				
8. Cost Estimate per Test			\$5000															\$26,000-\$46,000 for initial test depending on specifics \$5000/test thereafter				

Table C-5 (cont)

Organization No. 089
NL = Not listed
n/a = Not applicable

	AGING	Thermal	Radiation	Combined	HUMIDITY	STEAM ENVIRONMENT	Superheated	Saturated	PRESSURE	FUNCTION	Mechanical	Electrical	CHEMICAL SPRAY	VIBRATION	SEISMIC SIMULATION CONDITION	RADIATION	STEAM & CHEMICAL SPRAY	STEAM, RADIATION & CHEMICAL SPRAY	AGING & HUMIDITY	OTHER:	OTHER:	OTHER:
1. Number of Chambers		3	3		3		3	3	NL	NL			NL	NL	NL	3	NL	NL	NL			
2. Size/Volume of Chambers		82 in.³ to 3052 in.³	82 in.³ to 3052 in.³		8040 in.³ to 2880 in.³		9244 in.³ to 7680 in.³	9244 in.³ to 7680 in.³								603 in.³ to 10 ft³						
3. a. Size/Volume Over Which Flux Doesn't Vary More Than:																						
20%			82 in.³ to 3052 in.³		n/a		n/a	n/a								1 ft³						
50%			82 in.³ to 3052 in.³		n/a		n/a	n/a								69 in.³						
b. Radiation Sources Used			Nuclear Reactor, Co-60, PuBe, 14 MeV neutrons² 1x10¹⁵ n/s		n/a		n/a	n/a								100 kW Argonaut Reactor 14 MeV neutron generator PuBe Co-60						
4. Length of Time Environment Can Be Maintained if Limited			2 chambers while reactor is operating 3rd chamber no time limit		n/a		n/a	17 kW steam generator units								Reactor operating time ~8 h/day						
5. a. Rate of Application of Environment		As specified	$<10^3$ R/day to 10^7 R/day		Very quickly		NL	NL								NL						
b. How Rapidly Can Environment Be Established?																						
6. Active Variation of Environment		No	With client's needs		?		Valved, purged, etc.	Valved, purged, etc.								Changing reactor power or moving source						
a. How accomplished		n/a																				
b. Range achievable		n/a	$0 \rightarrow 10^7$ R/day		NL		NL	NL								$\gamma = 0 \rightarrow 6x10^6$ R/h $n = 0 \rightarrow 1x10^4$ R/h						
c. Smallest possible change		n/a	±10%		NL		NL	NL								±10%						
d. Manual variations		NL	NL		NL		NL	NL								NL						
7. Other Than Air Environments		N_2, etc. gases or vapors	No explosive vapors		n/a		n/a	n/a								Any nonexplosive or vaccum						
8. Cost Estimate per Test		NL	NL		\$5-15/h depending on needs		NL	NL								\$5 to \$65/h if reactor is used						

Table C-5 (cont)

Organization No. 133
NL - Not listed
n/a - Not applicable

	AGING	Thermal	Radiation	Combined	HUMIDITY	STEAM ENVIRONMENT	Superheated	Saturated	PRESSURE	FUNCTION	Mechanical	Electrical	CHEMICAL SPRAY	VIBRATION	SEISMIC SIMULATION CONDITION	RADIATION	STEAM & CHEMICAL SPRAY	STEAM, RADIATION & CHEMICAL SPRAY	AGING & HUMIDITY	OTHER:	OTHER:	OTHER:
1. Number of Chambers	NL				NL	NL			NL	NL			NL	NL	NL	2	NL	NL	NL			
2. Size/Volume of Chambers																1911 ft^3 & 6 in. diam. pipe						
3. a. Size/Volume Over Which Flux Doesn't Vary More Than:																Variable						
20%																						
50%																						
b. Radiation Sources Used																Co [illegible]						
4. Length of Time Environment Can Be Maintained if Limited																Within reason						
5. a. Rate of Application of Environment																Up to 10^6 R/h						
b. How Rapidly Can Environment Be Established?																						
6. Active Variation of Environment																						
a. How accomplished																By moving sources & changing geometry						
b. Range achievable																$<10^6$ R/h						
c. Smallest possible change																NL						
d. Manual variations																NL				R		
7. Other Than Air Environments																6 in. pipe Any nonexplosive gas, vacuum Hotcell- CO_2 or N_2						
8. Cost Estimate per Test																NL						

Table C-6

Select Manufacturers

Organization No. 007
NL = Not listed
n/a = Not applicable

	AGING	Thermal	Radiation	Combined	HUMIDITY	STEAM ENVIRONMENT	Superheated	Saturated	PRESSURE	FUNCTION	Mechanical	Electrical	CHEMICAL SPRAY	VIBRATION	SEISMIC SIMULATION CONDITION	RADIATION	STEAM & CHEMICAL SPRAY	STEAM, RADIATION & CHEMICAL SPRAY	AGING & HUMIDITY	OTHER:	OTHER:	OTHER:
1. Number of Chambers		3	2		NL		3	2	17		*	*	1			5	1 or as required	NL	3 (planned)			
2. Size/Volume of Chambers		3-8 in. dia x 20-30 ft	2 - 8 in. dia. x 1-15 ft.				≤1200 psi ≤1500 psi	283 ft³ 196 ft³	9.4 ft³ (≤1200 psi 750°F) 39 in.³ (10000 psi + 850°F)				448 ft³ w/ max section size 18 ft³ Up to 200°F			2-6 ft dia x 1-15 ft long, 3-8 in. dia x 20-30 ft long.	Up to 18 ft³ test section		2 in. dia x 6-15 ft long & 4 in. dia x ≈15 ft long			
3. a. Size/Volume Over Which Flux Doesn't Vary More Than:			For 10 ft chamber													For 10 ft chamber			For 15 ft chamber			
20%		n/a	4 ft length				n/a	n/a	n/a		n/a	n/a	n/a	n/a	n/a	4 ft	n/a		4 ft			
50%		n/a	8 ft length				n/a	n/a	n/a		n/a	n/a	n/a	n/a	n/a	8 ft	n/a		4 ft			
b. Radiation Sources Used		n/a	Spent fuel bundles & Co-60				n/a	n/a	n/a		n/a	n/a	n/a	n/a	n/a	Spent fuel & Co-60	n/a		Spent fuel bundles & heated test capsule			
4. Length of Time Environment Can Be Maintained if Limited		↓	Decay degeneration of spent fuel bundles, dosage function of time after removal from reactor				n/a	n/a	n/a		n/a	n/a	n/a if spray can be recycled	n/a on data storage only	n/a data storage seismic time history 80 s	Based on character of radiation source	n/a if spray can be re-cycled		Decay degeneration of SF bundle with time after reactor shutdown			
5. a. Rate of Application of Environment		Up to 1200°F duration dep. upon component	$1x10^6$ R/h to 0.1 R/h over 1000 h				$1.5x10^5$ lb/h	$1.5x10^5$ lb/h	n/a		NL	NL	NL	NL	NL	$1x10^6$ R/h to 0.1 R/h over 1000 h	NL		T - ≤400°F w/dosage rates up to 10^6 R/h from 1 R/h for 1000 h			
b. How Rapidly Can Environment Be Established?											↓	↓	↓	↓	↓							
6. Active Variation of Environment a. How accomplished		Programmed	Movement away from SF bundles				Venting, boiler firing rate, pressure relief valves		Venting or gas over pressure		Depending on test		Supply pressure to spray nozzle & rate of flow variation	Analog digital vibration control system	Analog digital vibration control system	Movement away from SF bundle	Supply pressure to spray nozzles & rate of flow variation		Lateral or vertical movement of SF bundles, programmed heater			
b. Range achievable		n/a	10^6 R/h to 1 R/h				0-100% void fraction + superheat pressure up to critical pressure		Full range		NL	NL	Up to 1000 psi Δp across nozzle	Sine sweep time history random multifreq. testing	NL	10^{10} R/h to 0.1 R/h	Up to 1000 psi Δp across nozzle		Inert gases, humidity other noncorrosive gases at 400°F max.			
c. Smallest possible change		n/a	~100 R/h				±10 psi ±2% volume flow rate		Gauge accuracy		NL	NL	n/a	NL	NL	~100 R/h	NL		Any so long as T reduction not required			
d. Manual variations		NL	NL				NL	NL	NL		NL	NL	n/a	NL	NL	NL	NL		NL			
7. Other Than Air Environments		Noncorrosive gases, (stainless steel) Vac. to 10^{-6} torr					n/a	n/a	n/a		n/a	n/a	n/a	n/a	n/a	Noncorrosive gas, vac. to 10^{-6} torr	n/a					
8. Cost Estimate per Test		NL	NL				NL	NL	NL		NL	NL	n/a	NL	NL	NL	NL		NL			

* Provided in attachment

Table C-6 (cont)

Organization No. 014
NL - Not listed
n/a = Not applicable

	AGING	Thermal	Radiation	Combined	HUMIDITY	STEAM ENVIRONMENT	Superheated	Saturated	PRESSURE	FUNCTION	Mechanical	Electrical	CHEMICAL SPRAY	VIBRATION	SEISMIC SIMULATION CONDITION	RADIATION	STEAM & CHEMICAL SPRAY	STEAM, RADIATION & CHEMICAL SPRAY	AGING & HUMIDITY	OTHER:	OTHER:	OTHER:
1. Number of Chambers		2	NL		NL		2	2	NL				2	NL	NL	NL	2	NL	NL			
2. Size/Volume of Chambers		$18\ ft^3$ & $50\ ft^3$					$4.7\ ft^3$ $10.6\ ft^3$				Shield room facility $2800\ ft^3$ for screen testing		$4.7\ ft^3$ $10.6\ ft^3$				$4.7\ ft^3$ $10.8\ ft^3$					
3. a. Size/Volume Over Which Flux Doesn't Vary More Than: 20%		n/a					n/a	n/a			n/a	n/a	n/a				n/a					
50%		n/a					n/a	n/a			n/a	n/a	n/a				n/a					
b. Radiation Sources Used		n/a					n/a	n/a			n/a	n/a	n/a				n/a					
4. Length of Time Environment Can Be Maintained if Limited		n/a					Steam inlet T ~ 425°F	150 lb. w/ present pressure vessels 200 lb boiler capacity					Pump required re-Building after ea. 30-day LOCA test to obtain flow at high pressure as in IEEE 323				Pump must be re-built after ea. test.					
5. a. Rate of Application of Environment		Rate dependent on material supplied -					Unknown	70 psig & 300°F in < 4 s			Variable						> 100 psig steam > 3 gal/soln.					
b. How Rapidly Can Environment Be Established?		Up to 260°C																				
6. Active Variation of Environment a. How accomplished		Cam drive recorder for recycling					Manual				Manual		Manual flow rate and chamber pressure				Manually					
b. Range achievable		n/a					5 to 200 psig				Equipment limits		As in IEEE 323				Steam pressure & flow rates					
c. Smallest possible change		n/a					1 psig based on visual accuracy				Usually limited		1%				±1%					
d. Manual variations		Periodic change in aging humidity					Same				NL		NL				NL					
7. Other Than Air Environments		but uncontrolled					n/a				n/a		n/a				n/a					
8. Cost Estimate per Test		$30/h tech, $50/h eng, $400/day facility for LOCA & specific set-up cost. Ave 30 day LOCA cost $21,500					$21,500 for 30 day test including set-up				$30/h tech $50/h eng.		$21,500 for LOCA profile				$21,500 per test (30 day) AC voltage and currents can also be applied.					

Table C-6 (cont)

Organization No. 101
NL = Not listed
n/a = Not applicable

	AGING	Thermal	Radiation	Combined	HUMIDITY	STEAM ENVIRONMENT	Superheated	Saturated	PRESSURE	FUNCTION	Mechanical	Electrical	CHEMICAL SPRAY	VIBRATION	SEISMIC SIMULATION CONDITION	RADIATION	STEAM & CHEMICAL SPRAY	STEAM, RADIATION & CHEMICAL SPRAY	AGING & HUMIDITY	OTHER:	OTHER:	OTHER:
1. Number of Chambers		NL	NL		NL	NL			NL				NL	NL	NL	1	NL	NL	NL			
2. Size/Volume of Chambers		NL	NL								n/a	n/a				4000 ft^3						
3. a. Size/Volume Over Which Flux Doesn't Vary More Than:																Depends on dose requirement conveyor system Provides uniform dose throughout						
20%		n/a	NL								n/a	n/a										
50%		n/a	NL								n/a	n/a										
b. Radiation Sources Used		n/a	Co-60								n/a	n/a				Co-60						
4. Length of Time Environment Can Be Maintained if Limited		NL	NL								n/a	n/a				n/a						
5. a. Rate of Application of Environment		NL	NL								As required					$0\text{-}10^8$ R/h						
b. How Rapidly Can Environment Be Established?																						
6. Active Variation of Environment a. How accomplished		T controller	Addition or subtraction of Co-60 pencils Movement with conveyor system or remote								Programmable controllers					Conveyor						
b. Range achievable		n/a	$0\text{-}10^8$ R/h								42°F up to ~ 2000°F depends on design (liquified metal temps up to ~ 1100°F)					$0\text{-}10^8$ R/h						
c. Smallest possible change		n/a	A few curies													A few curies						
d. Manual variations		NL	NL								NL	NL				Any required using slave manipulators						
7. Other Than Air Environments		Argon/Nitrogen									n/a	n/a				Small scale expts by using containment vessel. Any envir could be accommodated. Radiation room accommodates only air						
8. Cost Estimate per Test		Depends ~ $30/h labor									NL	NL				NL						

Table C-7

Select Testing Laboratories

Organization No. 003
NL - Not listed
n/a - Not applicable

	AGING	Thermal	Radiation	Combined	HUMIDITY	STEAM ENVIRONMENT	Superheated	Saturated	PRESSURE	FUNCTION	Mechanical	Electrical	CHEMICAL SPRAY	VIBRATION	SEISMIC SIMULATION CONDITION	RADIATION	STEAM & CHEMICAL SPRAY	STEAM, RADIATION & CHEMICAL SPRAY	AGING & HUMIDITY	OTHER:	OTHER:	OTHER:
1. Number of Chambers	NL				NL	NL			NL	NL			NL	NL	NL	3	NL	NL	NL			
2. Size/Volume of Chambers																225 ft^3						
3. a. Size/Volume Over Which Flux Doesn't Vary More Than:																						
20%																81 ft^3						
50%																125 ft^3						
b. Radiation Sources Used																Electron linac						
4. Length of Time Environment Can Be Maintained if Limited																n/a						
5. a. Rate of Application of Environment*																10^{11} Rad/s electrons-small vol. 5x10[illegible] Rad/s-γ large volume						
b. How Rapidly Can Environment Be Established?																NL						
6. Active Variation of Environment																Varying accelerator current energy						
a. How accomplished																						
b. Range achievable																e-10[illegible] R/s-10^{11} R/s γ 5x10[illegible] R/h-5x10[illegible] R/h [illegible]						
c. Smallest possible change																Continually variable						
d. Manual variations																NL						
7. Other Than Air Environments																Vacuum/spec. gas						
8. Cost Estimate per Test																NL						

Table C-7 (cont)

Organization No. 017
NL - Not listed
n/a - Not applicable

	AGING	Thermal	Radiation	Combined	HUMIDITY	STEAM ENVIRONMENT	Superheated	Saturated	PRESSURE	FUNCTION	Mechanical	Electrical	CHEMICAL SPRAY	VIBRATION	SEISMIC SIMULATION CONDITION	RADIATION	STEAM & CHEMICAL SPRAY	STEAM, RADIATION & CHEMICAL SPRAY	AGING & HUMIDITY	OTHER:	OTHER:	OTHER:
1. Number of Chambers		NL	NL	NL	Many		Many	Many	Many		None	None	NL		n/a	NL	NL	NL	NL			
2. Size/Volume of Chambers					Up to 5400 ft^3		NL	NL	Up to 735 ft^3		n/a	n/a		Answer depends on configuration	n/a							
3. a. Size/Volume Over Which Flux Doesn't Vary More Than:																						
20%					n/a		n/a	n/a	n/a		n/a	n/a		n/a	n/a							
50%					n/a		n/a	n/a	n/a		n/a	n/a		n/a	n/a							
b. Radiation Sources Used					n/a		n/a	n/a	n/a		n/a	n/a		n/a	n/a							
4. Length of Time Environment Can Be Maintained if Limited					n/a		n/a	n/a	n/a		n/a	n/a		n/a	n/a							
5. a. Late of Application of Environment					Hours		NL	NL	NL		NL	NL		n/a	n/a							
b. How Rapidly Can Environment Be Established?					NL		NL	NL	NL		NL	NL		n/a	n/a							
6. Active Variation of Environment		Automatic			Automatic		NL	NL	NL		NL	NL		NL	NL							
a. How accomplished																						
b. Range achievable		NL			NL																	
c. Smallest possible change																						
d. Manual variations																						
7. Other Than Air Environments																						
8. Cost Estimate per Test																						

Table C-7 (cont)

Organization No. 023
NL - Not listed
n/a - Not applicable

	AGING	Thermal	Radiation	Combined	HUMIDITY	STEAM ENVIRONMENT	Superheated	Saturated	PRESSURE	FUNCTION	Mechanical	Electrical	CHEMICAL SPRAY	VIBRATION	SEISMIC SIMULATION CONDITION	RADIATION	STEAM & CHEMICAL SPRAY	STEAM, RADIATION & CHEMICAL SPRAY	AGING & HUMIDITY	OTHER:	OTHER:	OTHER:
1. Number of Chambers		NL			Steam source, not chamber		2	2	2			NL	None	NL	NL	NL	NL	NL	NL			
2. Size/Volume of Chambers		Up to 1360 ft³			As needed		1260 ft³ up to 125 psia	1266 ft³ up to 125 psia	7 ft x 10 ft 2-50 psia 3 x 25 ft 2-125 psia		NL		n/a									
3. a. Size/Volume Over Which Flux Doesn't Vary More Than: 20%		n/a			n/a				n/a		n/a		n/a									
50%		n/a			n/a				n/a		n/a		n/a									
b. Radiation Sources Used		n/a			n/a				n/a		n/a		n/a									
4. Length of Time Environment Can Be Maintained if Limited		n/a			n/a		~10 h	Days	n/a		n/a		n/a									
5. a. Rate of Application of Environment		24 h for several mo			10 s		Seconds	Seconds	To 125 psia in 120 min.		Varies		Outdoor space for sprays									
b. How Rapidly Can Environment Be Established?		n/a																				
6. Active Variation of Environment		NL			Change air/steam pressure ratio		Vary air/steam pressure	Vary air/steam pressure	Bleed/feed air or steam		Depends		NL									
a. How accomplished																						
b. Range achievable					10-100% RH		15-125 psia	15-125 psia	2-125psia		NL											
c. Smallest possible change					~5% RH		5 psi, 5% RH	5 psi, 5% RH	~1 psia													
d. Manual variations					NL		n/a	n/a	n/a													
7. Other Than Air Environments					n/a		n/a	n/a	n/a													
8. Cost Estimate per Test					~$100,000		$30,000 up	$30,000 up	$15,000 to $100,000													

Table C-7 (cont)

Organization No. 026
NL = Not listed
n/a = Not applicable

	AGING	Thermal	Radiation	Combined	HUMIDITY	STEAM ENVIRONMENT	Superheated	Saturated	PRESSURE	FUNCTION	Mechanical	Electrical	CHEMICAL SPRAY	VIBRATION	SEISMIC SIMULATION CONDITION	RADIATION	STEAM & CHEMICAL SPRAY	STEAM, RADIATION & CHEMICAL SPRAY	AGING & HUMIDITY	OTHER:	OTHER:	OTHER:
1. Number of Chambers		5	5		NL		5	5	5		2	2	5	NL	NL	1	5	2	NL			
2. Size/Volume of Chambers		3,540 in.^{3} to 27,120 in.^{3}	3,540 in.^{3} to 27,120 in.^{3}				3,540 in.^{3} to 27,120 in.^{3}	3,540 in.^{3} to 27,120 in.^{3}	3,540 in.^{3} to 27,120 in.^{3}		20 ft^3 to 54 ft^3	20 ft^3 to 54 ft^3	3,540 in.^{3} to 27,120 in.^{3}			6000 ft^3	3,540 in.^{3} to 27,120 in.^{3}	13,560 in^3				
3. a. Size/Volume Over Which Flux Doesn't Vary More Than:			Depends on dose rate required													Depends on dose rate						
20%		n/a	2 volumes 50 ft^3				n/a	n/a	n/a		n/a	n/a	n/a			2 vol. 50 ft^3	n/a	entire volume				
50%		n/a	2 volumes 105 ft^3				n/a	n/a	n/a		n/a	n/a	n/a			2 vol. 105 ft^3	n/a	entire volume				
b. Radiation Sources Used		n/a	Co-60				n/a	n/a	n/a		n/a	n/a	n/a			Co-60	n/a	Co-60				
4. Length of Time Environment Can Be Maintained if Limited		n/a	n/a				Up to 80° of superheat	125 psig	n/a		n/a	n/a	n/a			n/a	n/a	n/a				
5. a. Rate of Application of Environment		Some 60 days norm 20-30 days	Some up to 150 days Norm 2? days for 200 Mrad				160°F/ min	160°F/ min	Depends on chamber size		As required	As required	0-5 gpm			25000r/h to $4x10^6$ r/h	Steam 0-125 psig spray 0-5 gpm	rad: 200 Mrad over 30 days				
b. How Rapidly Can Environment Be Established?																						
6. Active Variation of Environment a. How accomplished		Controls outside radiation area	Product movement				Pneumatic control	Pneumatic control	Automatic			Electrical insulation resistance apply 500 Vdc/m	NL			Move test item	Pneumatic controls	NL				
b. Range achievable		n/a	25000 r/h $4x10^6$ r/h				Up to 125 psig	Up to 125 psig				5 to ∞	NL			25000 r/h to $4x10^6$ r/h	125°F to 353°F steam 0-5 gpm	NL				
c. Smallest possible change		n/a	Within dosimetry limits 2-3%				None	None	2 psi			1 V	NL			5% of dose rate	3-5°F	NL				
d. Manual variations		NL	NL				n/a	n/a	n/a				Add acidic or alkaline solu. to vary pH of solution			NL	NL	NL				
7. Other Than Air Environments		Any gas	Any gas				n/a	n/a	n/a							Any nonexplosive gas in closed cont.		NL				
8. Cost Estimate per Test		IEEE-323 test sequential $15,-20,000 simultaneous $30,-35,000					16 day $8,000	30 day $11,000	Variable			~$600	$600			NL	$14,000	$30,000 to $40,000				

Table C-7 (cont)

Organization No. 051
NL - Not listed
n/a = Not applicable

	AGING	Thermal	Radiation	Combined	HUMIDITY	STEAM ENVIRONMENT	Superheated	Saturated	PRESSURE	FUNCTION	Mechanical	Electrical	CHEMICAL SPRAY	VIBRATION	SEISMIC SIMULATION CONDITION	RADIATION	STEAM & CHEMICAL SPRAY	STEAM, RADIATION & CHEMICAL SPRAY	AGING & HUMIDITY	OTHER:	OTHER:	OTHER:
1. Number of Chambers		24	NL		7		13	13	7		31	31	6	n/a	n/a	NL	7	NL	NL			
2. Size/Volume of Chambers		*																				
3. a. Size/Volume Over Which Flux Doesn't Vary More Than: 20%		n/a			n/a		n/a	n/a	n/a		n/a	n/a	n/a	n/a	n/a		n/a					
50%		n/a			n/a		n/a	n/a	n/a		n/a	n/a	n/a	n/a	n/a		n/a					
b. Radiation Sources Used		n/a			n/a		n/a	n/a	n/a		n/a	n/a	n/a	n/a	n/a		n/a					
4. Length of Time Environment Can Be Maintained if Limited		n/a			n/a		n/a	n/a	n/a		n/a	n/a	n/a	n/a	n/a		n/a					
5. a. Rate of Application of Environment		Dependent on material			As required		1,000 lb/h	40,000 lb/h	Dependent on chamber size		As required	As required	.5 to 20 gpm	HP 5425A digital vib. control system capability	n/a		Chamber temp. rise rate (max) 90°F/min					
b. How Rapidly Can Environment Be Established?																	Chamber temp. inlet steam T rise rate 600°F/min chem spray .5 to 20 gpm					
6. Active Variation of Environment a. How accomplished		Manual or automatic			Automatic		Input flow rate varied automatic	Input flow rate varied automatic	Automatically		As required	As required	Automatic	HP5425A	n/a		Automatically					
b. Range achievable		NL			20-98%		Inlet temp of chamber 600°F	Inlet temp of chamber 600°F			n/a	n/a	Boric acid NaOH ~~sodium~~ sulfate	Sine freq. & amplitude Random level & spectrum shape ~~velocity~~ Acceleration freq. PSD, Temp.			Chamber temp 212°F-500°F Chem flow 0.5 to 200 gpm					
c. Smallest possible change		NL			NL		5°F	5°F	2 psi		n/a	n/a	.05 gpm				Chamber temp 1°F/h Chem flow .05 gpm					
d. Manual variations		NL			NL		NL	NL	NL		NL	NL	NL				NL					
7. Other Than Air Environments		N_2			n/a		n/a	n/a	n/a		n/a	n/a	n/a	n/a			n/a					
8. Cost Estimate per Test		Variable			Cost depends on many conditions		Variable	Variable	Variable		Variable	Variable	Variable	Variable	$5,000 to $10,000		Variable					

*Chamber sizes are given in an attachment.

Table C-7 (cont)

Organization No. 057
NL - Not listed
n/a - Not applicable

	AGING	Thermal	Radiation	Combined	HUMIDITY	STEAM ENVIRONMENT	Superheated	Saturated	PRESSURE	FUNCTION	Mechanical	Electrical	CHEMICAL SPRAY	VIBRATION	SEISMIC SIMULATION CONDITION	RADIATION	STEAM & CHEMICAL SPRAY	STEAM, RADIATION & CHEMICAL SPRAY	AGING & HUMIDITY	OTHER:	OTHER:	OTHER:
1. Number of Chambers		5	NL		12		5	5	30		18	18	4	n/a	n/a	NL	4	NL	NL			
2. Size/Volume of Chambers		Up to 3744 ft^3			8 ft^3 to 3744 ft^3		NL	NL	6 in. x 1 ft to 6ft x 15 in.		Up to 3744 ft^3	Up to 3744 ft^3	Up to 6 ft x 15 ft	Up to 100,000 force lb.	n/a		Up to 6 ft x 15 ft					
3. a. Size/Volume Over Which Flux Doesn't Vary More Than:																						
20%		n/a			n/a		n/a	n/a	n/a		n/a	n/a	n/a	n/a	n/a		n/a					
50%		n/a			n/a		n/a	n/a	n/a		n/a	n/a	n/a	n/a	n/a		n/a					
b. Radiation Sources Used		n/a			n/a		n/a	n/a	n/a		n/a	n/a	n/a	n/a	n/a		n/a					
4. Length of Time Environment Can Be Maintained if Limited		n/a			n/a		n/a	n/a	n/a		n/a	n/a	n/a	n/a	n/a		n/a					
5. a. Rate of Application of Environment		As specified			Depends on specimen size & specific chamber		Depends on test	Depends on test	Depends, instantaneous to several minutes		Depends on duration of operating cycle		NL	Depends on specification requirement & size of test item	NL		NL					
b. How Rapidly Can Environment Be Established?							Seconds to hours	Seconds to hours														
6. Active Variation of Environment a. How accomplished		Controllers/ Recorders			Controllers/ recorders		Controller/ recorder/ regulation	Controller/ recorder/ regulation	Regulator		Standard special test equipment or manual control		Metering pumps & flow regulators	Electronic control	Electronically		Metering pumps & flow regulators					
b. Range achievable		n/a			3% to saturation		Ambient to several thousand psi for small; ambient to several hundred psi for large		10^{-5} torr to several thousand psi (~ 5000)		As specified		Up to 100 gpm	Sine, random & biaxial Dynamic with other envir.			Up to 100 gpm					
c. Smallest possible change		n/a			< 1%		Depends on test pressure level		~ 1% of indicated		Depends on capability of test equipment		~ 1%	< 5%	< 5%		~ 1%					
d. Manual variations		NL			NL		NL	NL	NL		NL	NL	NL	NL	NL		NL					
7. Other Than Air Environments		As specified excluding hazardous mat.			n/a		n/a	n/a	n/a		n/a	n/a	n/a	n/a	n/a		n/a					
8. Cost Estimate per Test		Depends on test configuration			Depends on test		NL	NL	NL		Depends on test	Depends on test	NL	NL	NL		NL					

Table C-7 (cont)

Organization No. 059
NL = Not listed
n/a = Not applicable

	AGING	Thermal	Radiation	Combined	HUMIDITY	STEAM ENVIRONMENT	Superheated	Saturated	PRESSURE	FUNCTION	Mechanical	Electrical	CHEMICAL SPRAY	VIBRATION	SEISMIC SIMULATION CONDITION	RADIATION	STEAM & CHEMICAL SPRAY	STEAM, RADIATION & CHEMICAL SPRAY	AGING & HUMIDITY	OTHER:	OTHER:	OTHER:
1. Number of Chambers		3 + 20 from Subcontractor	3 + 20 from Sub-contractor		1 + 10 from Subcontractor		3	3	NL		n/a	n/a	2			1 subcontracted	2 subcontracted	NL	NL			
2. Size/Volume of Chambers		24 ft^3 to 140 ft^3	24 ft^3 to 140 ft^3		24 ft^3 to 3750 ft^3		62,520 $in.^3$	62,520 $in.^3$	NL		n/a	n/a	62,520 $in.^3$	As required		3750 ft^3	62,520 $in.^3$					
3. a. Size/Volume Over Which Flux Doesn't Vary More Than: 20%		n/a	3000 ft^3		n/a		n/a	n/a	n/a		n/a	n/a	n/a	n/a	n/a	3000 ft^3	n/a					
50%		n/a	1000 ft^3		n/a		n/a	n/a	n/a		n/a	n/a	n/a	n/a	n/a	1000 ft^3	n/a					
b. Radiation Sources Used		n/a	100 K curies CO-60 ~30 pencils		n/a		n/a	n/a	n/a		n/a	n/a	n/a	n/a	n/a	CO-60 pencils up to 100 K curies	n/a					
4. Length of Time Environment Can Be Maintained if Limited		n/a	n/a		n/a		n/a	n/a	n/a		n/a	n/a	n/a	n/a	n/a	n/a	n/a					
5. a. Rate of Application of Environment		100 days @ 150° to 300°F	1 Mrad/h		1 h to equilibrium		NL	NL	0 → 100 psig in 10 s max.		As generated by test structure or mechanism		0.25 gal/min/ft^2	As required	As required	1 Mrad/h	Chem spray @ 0.25 gal/ft^2/min					
b. How Rapidly Can Environment Be Established?																	Steam @ 0 → 100 psig in 10 s					
6. Active Variation of Environment a. How accomplished		Programmable cams	ND remote changing of pencil positions		Programmable cams		Programmable cams on pressure or T controls		Program cam or pressure controller		As generated by test structure or mechanism		No	Programmed tape	Programmed tape	Remote movement of pencils	No					
b. Range achievable		n/a	0.1 Mrad/h		0-98%		NL	NL	0 → 100 psig		NL	NL	NL	As required	1-50 Hz @ 0.1 to 10g respon.	0 → 1 Mrad/h	NL					
c. Smallest possible change		n/a	0.01 Mrad/h		±2% R.H.		±2°F of	±2 psig	±2 psig		NL	NL	NL	±1 Hz @ ±0.001 g input	±1 Hz @ ±0.001 g input	0.01 Mrad/h	NL					
d. Manual variations		NL	n/a		NL		NL	NL	NL		NL	NL	Needle valve control	NL	NL	NL	Needle valve control on steam chem spray, in power to super heater by T controller					
7. Other Than Air Environments		NL	n/a		NL		n/a	n/a			n/a	n/a	n/a	n/a	n/a	Vacuum & spec. gas						
8. Cost Estimate per Test		NL	NL		$150-1[illegible] per test day		~ $500/day (24-h day)		~$200/1-st day		$3000-$150,000 for simple 1-5 channel, 3-4 day, test program to full scale structure tests requiring 3-4 wk effort		NL	$500/min ave. cost 500-1000 per item. IEEE 344-1975 for class IE	NL	NL	NL	↓	↓			

Table C-7 (cont)

Organization No. 065
NL = Not listed
n/a = Not applicable

	AGING	Thermal	Radiation	Combined	HUMIDITY	STEAM ENVIRONMENT	Superheated	Saturated	PRESSURE	FUNCTION	Mechanical	Electrical	CHEMICAL SPRAY	VIBRATION	SEISMIC SIMULATION CONDITION	RADIATION	STEAM & CHEMICAL SPRAY	STEAM, RADIATION & CHEMICAL SPRAY	AGING & HUMIDITY	OTHER:	OTHER:	OTHER:
1. Number of Chambers		Fabricate as needed			NL	NL			NL	NL			NL			NL	NL	NL	NL			
2. Size/Volume of Chambers		NL	NL											Up to 6000 ft³	Up to 6000 ft³							
3. a. Size/Volume Over Which Flux Doesn't Vary More Than:																						
20%														n/a	n/a							
50%														n/a	n/a							
b. Radiation Sources Used														n/a								
4. Length of Time Environment Can Be Maintained if Limited														10,000 lb for 30 s current system design at max output	Same as vibration							
5. a. Rate of Application of Environment														?	?							
b. How Rapidly Can Environment Be Established?																						
6. Active Variation of Environment																						
a. How accomplished														Amplitude & time history varied electrically or manually	Same as vibration							
b. Range achievable														NL	NL							
c. Smallest possible change														~2%	~2%							
d. Manual variations														NL	NL							
7. Other Than Air Environments														n/a	n/a						*	
8. Cost Estimate per Test														Variable	~$10,000 for 3000 lb item							

Table C-7 (cont)

Organization No. 067
NL = Not listed
n/a = Not applicable

	AGING	Thermal	Radiation	Combined	HUMIDITY	STEAM ENVIRONMENT	Superheated	Saturated	PRESSURE	FUNCTION	Mechanical	Electrical	CHEMICAL SPRAY	VIBRATION	SEISMIC SIMULATION CONDITION	RADIATION	STEAM & CHEMICAL SPRAY	STEAM, RADIATION & CHEMICAL SPRAY	AGING & HUMIDITY	OTHER:	OTHER:	OTHER:
1. Number of Chambers		3 bench top oven & 2 larger	This is sub-contracted		1		5	5	5		NL	NL	5			NL	5	2	2			
2. Size/Volume of Chambers		Smaller bench top to 36 ft^3			8 ft^3		936 in.^{3} to 129,600 in.^{3}	936 in.^{3} to 129,600 in.^{3}	936 in.^{3} to 129,600 in.^{3}		NL	NL	936 in.^{3} to 129,600 in.^{3}	8 in D, 3…, 7000 lb force shake table; Also, 0.25g, 300 lb, 60 Hz vibration			936 in.^{3} to 129,600 in.^{3}	21,700 in.^{3}	21,700 in.^{3}			
3. a. Size/Volume Over Which Flux Doesn't Vary More Than:																						
20%		n/a	NL		n/a		n/a	n/a	n/a		n/a	n/a	n/a	n/a	n/a		n/a	Sub-	Sub-			
50%		n/a	NL		n/a		n/a	n/a	n/a		n/a	n/a	n/a	n/a	n/a		n/a	contracted	contract…			
b. Radiation Sources Used		n/a	Usually Co-60		n/a		n/a	n/a	n/a		n/a	n/a	n/a	n/a	n/a		n/a	Co-60				
4. Length of Time Environment Can Be Maintained if Limited		n/a	n/a		n/a		n/a	n/a	n/a		n/a	n/a	Limited by 20000 gal storage capacity	n/a	n/a		n/a	n/a	n/a			
5. a. Rate of Application of Environment		121°C → 300°C	0.1-1.0 Mrad/h		1 mm		~2000#/h for a few min	5000#/h steady 10,000#/h surge	~2 psig/min		Dependent on nature of test		5 gph → 5 gpm	NL	NL		~2000#/h for few min 5000#/h steady	Radiation subcontracted 150 psig	NL			
b. How Rapidly Can Environment Be Established?																	10000#/h surge	steam 5 gpm chemical spray				
6. Active Variation of Environment a. How accomplished		Automatic	No discrete steps: changing source/spec separation		Cam follower programmer		Adjustment of steam pressure		Addition or release of pressure		Various ways appropriate to function		Bypass & throttling valves	Control adjustment			Manual adjustment of controls	Adjustment of controls	NL			
b. Range achievable		n/a	0.1-3.0 Mrad/h		20-95% RH		0-150 psig		0-200 psig				5 gph → 5 gpm	Sine, sweepsine, multifrequency, sine beat			140 psig steam max.	NL	NL			
c. Smallest possible change		n/a	0.1 Mrad/h		few %		1 psig		1 psig		~1% of span		~1% of span	NL	NL		1 psig	NL	NL			
d. Manual variations		NL	n/a		NL		NL	NL	NL		NL	NL	NL	NL	NL		NL	NL	NL			
7. Other Than Air Environments		NL	NL		n/a		n/a	n/a	n/a		n/a	n/a	n/a	n/a	n/a		n/a	n/a	n/a			
8. Cost Estimate per Test		NL	NL		$3000		$5000/1 day test $15000/30 day test		$5000		~$5000		$10,000	$5,000			$15,000 30 day test	$40,000	$15,000			

Table C-7 (cont)

Organization No. 077
NL = Not listed
n/a = Not applicable

	AGING	Thermal	Radiation	Combined	HUMIDITY	STEAM ENVIRONMENT	Superheated	Saturated	PRESSURE	FUNCTION	Mechanical	Electrical	CHEMICAL SPRAY	VIBRATION	SEISMIC SIMULATION CONDITION	RADIATION	STEAM & CHEMICAL SPRAY	STEAM, RADIATION & CHEMICAL SPRAY	AGING & HUMIDITY	OTHER:	OTHER:	OTHER:
1. Number of Chambers		17	17		8		6	6	5		5-17 as necessary		4			NL	4	NL	NL			
2. Size/Volume of Chambers		4.5 ft³ to 19,040 ft³	4.5 ft³ to 19,040 ft³		15.6 ft³ to 19,040		21,700 in.³ to 512 ft³	21,700 in.³ to 512 ft³	21,700 in.³ to 283 ft³		As needed		21,700 in.³ to 283 ft³	4x4ft bi-axial table 2x2 ft single axis vib table, 8x8 ft bi-axial vib. table, Ling 249 Ling 335			54,240 in.³ to 283 ft³					
3. a. Size, [illegible] me Over Which Flux Doesn't Vary More Than:																						
20%		n/a	sub-		n/a		n/a	n/a	n/a		n/a	n/a	n/a	n/a	n/a		n/a					
50%		n/a	contractor		n/a		n/a	n/a	n/a		n/a	n/a	n/a	n/a	n/a		n/a					
b. Radiation Sources Used		n/a	Co-60 or linear acc.		n/a		n/a	n/a	n/a		n/a	n/a	n/a	n/a	n/a		n/a					
4. Length of Time Environment Can Be Maintained if Limited		n/a	n/a		n/a		425°F w/100 psig or 650°F w/less than 1 psig	150 psig 365°F	n/a		n/a	n/a	n/a	n/a	n/a		n/a					
5. a. Rate of Application of Environment		Depends on test	Subcontracted		No greater than 30 min.		400°F/min or 100°F/min	300°F/min	1 psi/min		As required		As required	As required			300°F/min 1 gal/min per ft² of chamber or test item					
b. How Rapidly Can Environment Be Established?																						
6. Active Variation of Environment a. How accomplished		T controller is prog. to change heat input	Subcontractor may also be able to do this		Dehumidifiers & introduction of dry air		Steam input to chamber is varied.		Venting or changing source pressure		Automatically and manually as necessary		Change source reservoir from which spray is drawn	"G" level, frequency may be changed	Conditions may be varied changing inputs to vibration exciter		Steam input to chamber is varied					
b. Range achievable		n/a	NL		~30% to 100%		Up to 650°F 0 psig	Up to 365°F	Up to 1000 psig		As required		Deionized water to boric acid	1-2000 Hz, 0-30 g's	0-5 g 1-100 Hz		Up to 365°F satu. steam, up to 1 gal/min/ft² of chamber or test item					
c. Smallest possible change		n/a	NL		2.5%		up to 425°F w/up to 100 psig ~5°F	~5°F	1 psi		Any increment required		pH - .5 unit	0.1 Hz 0.1 g	0.1 Hz 0.05 g		5°F					
d. Manual variations		NL	NL		NL		n/a	n/a	n/a		n/a	n/a	n/a	n/a	n/a		n/a					
7. Other Than Air Environments		Liquid hot bath	n/a		n/a		n/a	n/a	n/a		n/a	n/a	n/a	n/a	n/a		n/a					
8. Cost Estimate per Test		Depends $200 to $50,000			Depends		$23/h	$23/h	Variable		Depends on test		Depends on test	Depends on test	Depends on test		Depends on test					

Table C-7 (cont)

Organization No. 092
NL = Not listed
n/a = Not applicable

	AGING	Thermal	Radiation	Combined	HUMIDITY	STEAM ENVIRONMENT	Superheated	Saturated	PRESSURE	FUNCTION	Mechanical	Electrical	CHEMICAL SPRAY	VIBRATION	SEISMIC SIMULATION CONDITION	RADIATION	STEAM & CHEMICAL SPRAY	STEAM, RADIATION & CHEMICAL SPRAY	AGING & HUMIDITY	OTHER:	OTHER:	OTHER:
1. Number of Chambers		6-10	2		2	NL			NL		Can handle almost anything except those requiring very high power requirements or steam flow rates		NL			2	NL	NL	NL			
2. Size/Volume of Chambers		40 ft^3 & smaller Up to 1 64 ft	10x10 ft rooms		4 ft^3									Biaxial hydraulic 6000 lb load at limit, 200 shaker-2000 lb force, Uniaxial hydraulic table 6000 lb limit	Hydraulic actuated biaxial shaker	~10x15 ft rooms						
3. a. Size/Volume Over Which Flux Doesn't Vary More Than:			Depends on flux level													Depends on dose rate						
20%		n/a			n/a						n/a	n/a		n/a	n/a							
50%		n/a			n/a						n/a	n/a		n/a	n/a							
b. Radiation Sources Used		n/a	Co-60		n/a						n/a	n/a		n/a	n/a	Co-60						
4. Length of Time Environment Can Be Maintained if Limited		n/a	n/a		n/a						NL	NL		n/a	NL	n/a						
5. a. Rate of Application of Environment		?	?		NL						NL	NL		?	NL	NL						
b. How Rapidly Can Environment Be Established?																						
6. Active Variation of Environment a. How accomplished		Temp. controller	Moving sources w/remote manipulators											Sweep generator for sine excitation	Electronic control	Remote manipulators i.e., move the source						
b. Range achievable		n/a	0-2 Mrad/h											1-200 Hz Hydraulic 5-Hz to 10KHz EM shaker	NL	NL						
c. Smallest possible change		n/a	?											NL	NL							
d. Manual variations		NL	NL											NL	NL							
7. Other Than Air Environments		NL	n/a											n/a	n/a							
8. Cost Estimate per Test		NL	NL											NL	NL							

Table C-7 (cont)

Organization No. 098
NL = Not listed
n/a = Not applicable

	AGING	Thermal	Radiation	Combined	HUMIDITY	STEAM ENVIRONMENT	Superheated	Saturated	PRESSURE	FUNCTION	Mechanical	Electrical	CHEMICAL SPRAY	VIBRATION	SEISMIC SIMULATION CONDITION	RADIATION	STEAM & CHEMICAL SPRAY	STEAM, RADIATION & CHEMICAL SPRAY	AGING & HUMIDITY	OTHER:	OTHER:	OTHER:
1. Number of Chambers		3	NL	n/a	3		1		1		Any	Any	LTV EM system Unholtz Dickie EM system		As in vibration	1	n/a	n/a	1			
2. Size/Volume of Chambers		Max 0.73 m^3	NL		Max 0.73 m^3		Maximum penetration 8.25 cm diameter				None	None	1000 # max depending on Hz and G load		As in vibration	n/a			0.73 m^3			
3. a. Size/Volume Over Which Flux Doesn't Vary More Than:																						
20%		n/a	NL		n/a		n/a	n/a	n/a		n/a	n/a		n/a	n/a	NL			NL			
50%		n/a	NL		n/a		n/a	n/a	n/a		n/a	n/a		n/a	n/a	NL			NL			
b. Radiation Sources Used		n/a	Co-60		n/a		n/a	n/a	n/a		n/a	n/a		n/a	n/a	Co-60			Co-60			
4. Length of Time Environment Can Be Maintained if Limited			n/a		n/a		900°C at 5.52 MPa	NL	n/a		n/a	n/a		None	None	NL			None			
5. a. Rate of Application of Environment		Up to 150°C	Up to ~100 R/h		NL		NL	NL	NL		NL	NL		NL	NL	Bkgd to 100 R/h on small pieces			0-100 R/h on small pieces			
b. How Rapidly Can Environment Be Established?					Few minutes		NL	NL	NL		NL	NL		n/a	n/a	NL			NL			
6. Active Variation of Environment a. How accomplished		Recording Controller	Physical movement of sources		Control of H_2O flow & T		Steam rate and Chamber T		Compressor and bleed off Control		Depends on function and equipment configuration			NL	NL	Physical movement of source			Physical movement of source			
b. Range achievable		NL	0-100 R/h		0-100%		900°C @ 5.52 MPa	NL	Up to 5.52 MPa		NL	NL		Ambient room	Ambient room	0-100 R/h			NL			
c. Smallest possible change		NL	As required		±2%		NL	NL	±2 kPa		NL	NL		Few % of parameter	Few % of parameter	NL			NL			
d. Manual variations		n/a	n/a		n/a		n/a	n/a	n/a		NL	NL		n/a	n/a	n/a			NL			
7. Other Than Air Environments		Low pressure & noncorrosive gas atmosphere			n/a		n/a	n/a	n/a		n/a	n/a		n/a	n/a	No			NL			
8. Cost Estimate per Test		NL	NL		NL		NL	NL	NL		NL	NL		NL	NL	NL			NL			

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This study provides an analysis of alternatives for conducting independent verification testing of environmentally qualified safety-related equipment which is required to operate in nuclear plant safety systems. Three major alternatives were costed and compared: (1) NRC dedicated test facility; (2) NRC contracts for testing to existing test laboratories; (3) NRC review and witnessing of vendor tests.

To formalize the evaluation, eleven specific criteria were identified against which the alternatives were compared. None of the alternatives singly show clear advantage; but in the dual combinations, an "optimal" alternative emerges when alternatives 1 and 3 are considered in union.

This study also illustrates the magnitude and immediacy of the equipment environmental qualification issue. It recommends that dedicated NRC staff be assigned to qualification programs review and that other NRC staff continue this study to define, coordinate, and implement an optimal alternative. NRC action resulting from this study is identified in a May 1980 Commission Paper.

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